Water management in Ontario

Ontario
Water Resources
Commission

Public Relations
and Information

Readings In Water Management

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PREFACE

Management of our water involves many sciences, all of which are correlated into a pattern of effort designed to evaluate, assess and plan for the use, protection and inventory of our water resources. This is being done to meet current and future needs and the demands of individuals, municipalities, industries, agriculturalists and the aquatic environment.

Many considerations are involved in the management program such as waste input, nutrient build-up, flow, precipitation, silt sedimentation, aquatic growth, forestation, runoff, soil erosion, and most important of all, the use to be made of the waters.

What has been attempted in this book of readings is to present some technical highlights of some of the important aspects relating to our basic water problems.

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WATER IN ONTARIO

The total area of Ontario is 412,582 square miles, of which it is estimated 68,490 square miles or 17 per cent is lakes and rivers.

There are an estimated 2,362 miles of fresh water and 680 miles of salt water shoreline of important bodies of water within the province. The Great Lakes - St. Lawrence waterway constitute a large part of the surveyed fresh water shoreline.

The Great Lakes constitute one of the most important inland waterways in the world, and one of Ontario's greatest assets. The total drainage area of these lakes is 295,200 square miles, of which 122,040 square miles lies within the borders of Ontario. The attached table gives some pertinent information regarding these lakes.

Ontario has an abundant supply of inland lakes and rivers, with most of the largest being located in northern Ontario. The largest of the northern rivers is the Albany system which has a drainage area of 52,300 square miles. In all, the northern rivers draining into Hudson Bay cover an area of 271,342 square miles. This constitutes about 66 per cent of the entire area of the province.

The largest river system in southern Ontario is the Ottawa River (Ontario - Quebec border) which has a drainage area of 19,200 square miles. The second largest is the Trent system which has a drainage area of approximately 4,700 square miles, and the third is the Grand River system which drains 2,614 square miles.

Of the land surface within the province draining to the Atlantic Ocean, the Great Lakes - St. Lawrence land surface accounts for the drainage of 87,820 square miles, and that of the Ottawa River, 19,200 square miles. The Great Lakes water surface accounts for another 34,220 square miles.

The average annual precipitation is approximately 28 inches in northern Ontario and 33 inches in Southern Ontario. It varies from 18 inches along the Ontario-Manitoba border to about 40 inches at various locations in the lee of the Great Lakes.

GREAT LAKES DATA

				Surface Area		Drainage Area	
Lake	Length Miles	Width Miles	Depth Feet	Total Sq. Miles	Ontario Sq. Miles	Total Sq. Miles	Ontario Sq. Miles
Superior	383	160	1,302	31,820	11,110	80,000	43,330
Michigan	321	118	923	22,400	0	67,860	0
Huron	247	101	750	23,010	13,900	72,620	47,570
St. Clair	26	24	23	490	280	7,430	4,110
Erie	241	57	210	9,930	4,950	32,490	11,110
Ontario	193	53	778	7,520	3,980	34,800	15,920

In terms of gallons, precipitation of 30 inches annually over the 412,582 square miles of the province amounts to approximately 180,000 billion gallons or 1,200,000 gallons per day per square mile. However, making allowance for evaporation and transpiration losses, which can account for as much as 60 per cent, and other complicated hydrologic and geologic factors, the estimated total amount of fresh water available for use by man annually in Ontario is reduced to 94 billion gallons per day or approximately 15,000 gallons per day for each person.

GROUND WATER

Ground water is that which occurs below the surface of the ground in the zone of saturation, where all pore spaces and fractures are filled with water. The surface of the saturated zone, which may be close to or far below the land surface, is called the water table. A formation which will hold, transmit and yield ground water in usable quantities is known as an aquifer.

It is estimated that half of the water available to man through precipitation enters the ground water system. In sandy areas the rate of infiltration is higher than in clay areas and the amount of water entering the aquifer is greater. The amount and intensity of rainfall, the nature of soil and vegetation, the slope of land surface, and wind and temperature conditions all play a part in governing the amount of water entering the underground system.

The amount of water which can be removed in any specific area depends on the character of the aquifer and the amount of recharge. Fine-grained materials such as clay or silt, have high porosities and abilities to hold large quantities of water in storage but water has a hard time passing through them and this feature makes them a poor source of supply. Coarse sediments such as coarse sands and gravels pass water through easily and are usually good sources of water supply.

A great deal is still to be learned about our water resources and includes such things as quality and quantity variations and the relationships between the various hydrologic factors affecting our waterways.

Water Use:

Some 30 per cent of Ontario's population is dependent on individual ground and surface water systems. These are located for the most part, in rural areas of the province.

The average rural homeowner uses approximately 50 gallons of water daily and it has been estimated that rural needs, apart from irrigation, collectively amount to approximately 100 million gallons per day.

Water used for irrigation, which is considered to be a consumptive use because an estimated 65 to 95 per cent is not available for re-use, has been estimated at approximately two billion gallons a day during the irrigation season.

Urban domestic, commercial and municipally-supplied industry uses a steadily increasing amount of water. In 1970 some 700 communities in Ontario were served by municipal water-works systems which supplied an estimated 1 billion gallons of water daily. Approximately 60 per cent of the water supplied by municipal systems was drawn from the Great Lakes - St. Lawrence system, with about 20 per cent from ground water sources and 20 percent from inland surface water.

A community with little or no industry has an average per person consumption of from 50 to 60 gallons of water daily. This will increase to around 100 gallons per day with a moderate amount of lawn watering and industrial use, and may exceed 200 gallons per day if considerable water is supplied to industry through the waterworks system.

The heaviest demands on our water resources are made by industry. Studies have indicated that private industrial water use varies from five to ten times higher than that supplied by municipal systems. The amount used by private industry from their own ground or surface water sources is estimated at four billion gallons daily. This estimate does not include water used for the generation of electricity.

In all, the present industrial, agricultural and municipal withdrawal of water for all purposes amounts to approximately seven billion gallons per day. This is only a small portion of the 94 billion gallons per day theoretically available. However, the remoteness of much of this available water from many areas of the province where it is required

reduces this figure in relation to any specific area, sometimes to the point of shortages.

HISTORICAL CONSIDERATIONS

In order to generalize the effect of growth on a watershed, it would help to historically recount some of the important aspects which have a bearing on this development.

In early pioneer days a nameless watershed formed a river flowing through a bountiful forest which in turn discharged into a clear lake. The area was populated by the occasional Indian village.

As settlement began, land was cleared of forest and became farms. Eventually communities began to develop which cut further into forests not only for the townsite but for the timber to construct dwellings.

Over the years the forest cover was gradually reduced to feed the needs of a growing population. Swamp and marsh areas were drained to accommodate the rising need for more farmland.

The growing settlement's demand for water grew. Hundreds then thousands of wells were dug. The lake and river and its tributaries began to take the wastes from this development in ever increasing volumes.

Finally industry began to develop in the area and added its own share to the needs for water, land and places to dispose of process wastes.

The overall effects of this development went unnoticed when the population was small. But, as the population increased and spread throughout the watershed, and the established communities began to grow in size with the development of industry, the overall effects slowly began to become apparent.

Marshland, which was once used to recharge ground water aquifers, was cultivated and not only reduced the amount of rainfall able to enter the aquifer but increased the amount of runoff.

Forest cover now removed could no longer retain water required by the ground and caused further runoff; much of which carried away valuable topsoil.

During periods of heavy rain or rapid melting of snow, surface waterways flooded and inundated communities and homes along the banks, eroding the banks of the river itself, as the river was unable to handle the ever increasing amounts of runoff. Lake levels fluctuated violently.

Community, industrial and agricultural wastes began to change or destroy the aquatic life in the lake and river and the banks of both became unsightly, giving off offensive odours.

Ground water levels dropped and during periods of dry weather the rivers' flow decreased to nearly a trickle. The effects of continuous neglect were now more than obvious. Lack of a proper water management program for the developmemt of the area had left its mark.

WATER POLLUTION

According to the dictionary, "to pollute" means to destroy the purity of, make foul or filthy"; therefore, water pollution means the destruction of the purity of water by impairing its quality to a point where it becomes unfit for the many uses for which it is intended.

Human wastes, industrial wastes, farm animal wastes, pesticides, herbicides, old tires, tin cans, and garbage of any kind are pollutants. Any measureable quantity of any of these pollutants in a waterway is pollution.

Water pollution endangers health, it adversely affects our commercial and sport fishing, it robs us of recreational areas, it reduces property values by detracting from the appearance and usefulness of land and buildings, it impairs the quality of drinking water supplies and makes it costly to treat, it damages bridges, docks and boat hulls, and it destroys wildlife.

Pollution may cause water to become foul, septic and unsightly, resulting in strong odours. It may deplete the oxygen content of the water to a point where fish and other aquatic life can barely exist or are destroyed.

Today, from the discoveries of Pasteur, Koch and Lister, we know of the dangers that may lurk in even clear, odourless water. Science protects us from the dangers of typhoid fever, endemic diarrhea, dysentery and related diseases of the environment. However, just because we have been fortunate in having few outbreaks of water-borne diseases in recent years, this does not mean that we are free from danger: pollution can become a potent source of infection at any time.

POLLUTION CONTROL

There are basically two methods of waste treatment: natural and artificial or man-made.

Natural processes enable water to purify itself by bleaching from sunlight; dilution; settling of wastes to the bottom; oxidation and by the action of bacteria. However, when man overloads the natural capabilities of water, he must provide an alternative method of treatment which must not only be corrective, but also preventive.

Methods of waste treatment have been developed to a sophisticated degree in recent years. A very high percentage of solid, suspended and dissolved pollutants can be removed by selecting the proper treatment.

One of these sophisticated methods adapted by the OWRC is a phosphorous removal process which will eliminate a minimum of 80% of phosphorous from sewage. This will significantly control the input of nutrients which cause excessive algae growth in our waterways, and will provide a stimulus to the recovery of affected waters.

Sewage treatment processes are costly in terms of capital outlay, but the overall, long-term advantages to pollution abatement are indisputable.

There are no easy answers to the problems associated with the treatment of liquid wastes. Industries, agriculture, academics and government agencies must continue to expand and increase their research to find the sollutions. The readings that follow will describe some of the research and some of the problems encountered.

WATER QUALITY REQUIREMENTS

FOR

MUNICIPAL AND INDUSTRIAL USES

by

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ONTARIO WATER RESOURCES COMMISSION

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INTRODUCTION

Water, the most abundant compound on the face of the earth, is called upon to serve many purposes ranging from internal consumption by living organisms, through agricultural and industrial uses, to the exploitation of its remarkable powers to transport and assimilate the wastes of civilization. (1) The many purposes that water serves in promoting the economic good and well-being of man-kind are known as beneficial uses. The beneficial uses, not listed in order of economic importance, can be broadly categorized as follows:

Agricultural Water Supply
Protection of Fish, Other Aquatic Life and Wildlife
Industrial Water Supply
Public Water Supply
Aesthetics and Recreation
Water Power and Navigation
Transport, Dispersion and Assimilation of Wastes

The relative importance of these beneficial uses for any stream, lake, open ocean, estuary, or ground water basin depends on the economy of the area and the desires of the inhabitants. Many of the uses, such as domestic water supply and industrial-process water supply, may be compatible within narrow ranges of water quality, whereas the use of a stream for unregulated waste disposal may be at complete variance with its use for domestic water supply. Use of water is related to its quality which is described by such indicators as temperature, pH, chloride, dissolved solids and dissolved oxygen.

This paper revolves around the topic of water quality requirements for municipal and industrial purposes. The term 'municipal' includes both domestic and industrial uses, however, I have considered the prime municipal use as domestic water supply as would be normally furnished by public utilities to built-up areas.

Also, the term 'requirement' needs some clarification. In this paper, I shall actually be talking about water quality criteria for certain uses, although among some water pollution control authorities, the terms criteria and requirements are often interchangeable. Terminology is troublesome in this area and I propose to define several terms from the outset in order to avoid any confusion which might arise.

The term 'standard' (2) applies to any definite rule, principle, or measure established by authority but this fact does not necessarily mean that the standard is fair, equitable, or based on sound scientific knowledge, although it should be. The word 'objective' represents an aim or goal toward which to

strive and it may designate an ideal condition; however, it does not imply strict adherence, nor enforcement, by an agency. "Criteria' are scientific data or information on which a decision or judgement may be based concerning the suitability of water to support a designated use. Unlike a standard, it carries no connotation of authority other than that of fairness and equity, nor does it imply an ideal condition. In Ontario, the term 'requirement' is generally used in relation to effluents to designate the maximum allowable waste loading which may be discharged to a receiving body of water. For example, The Ontario-Minnesota Pulp and Paper Company Limited, a subsidiary of Boise Cascade, is building a new 500 ton per day draft mill in Northwestern Ontario on the Rainy River. Biological and water quality studies have been carried out on this River, including an estimate of the assimilative capacity of the River and an analysis of the various uses of the River. The Company was allocated a maximum permissible discharge - an effluent requirement or limit - of 10,000 pounds of BOD5 per 24-hour day based on specific water quality conditions to be preserved in the River.

THE NEED FOR WATER QUALITY CONTROL

Control of water quality is necessary if water-use conflicts are not to arise. To illustrate this point, a number of water-use conflicts which have occurred in Ontario over the past two decades will be briefly outlined. For example, high chloride discharges from a large chemical complex on the St. Clair River system have apparently caused minor corrosion problems from time to time in heat exchange systems of downstream chemical industry. A number of rivers in Ontario have been polluted from pulp and paper mill wastes such that fish life is non-existent for many miles thus reducing the recreational value of these river systems. In the case of kraft mills, tainting of fish flesh has occurred in downstream waters where fish species do exist thus destroying previously valuable and viable commercial fisheries. In the mid-sixties, several incidents occurred involving livestock dying from ingesting creek water flowing through farmlands in Southern Ontario. The creek was polluted by partially treated wastes from a chemical plant manufacturing herbicides, antioxidants and other specialty chemicals. The capacity of the stream was not enough to render harmless the residual toxic effects of the treated wastes, thus conflict with the traditional usage for livestock watering was created. Fibrous solids from pulp and paper mill effluents have travelled downstream and clogged water intake screens of

other industry, and caused water quality problems such as high turbidity at other points of use. Arsenic losses from a now defunct mining and milling operation in Eastern Ontario have raised the arsenic concentration in downstream waters used for domestic purposes above the acceptable limit for all-year-round ingestion - an obvious conflict between industrial and domestic use. And of course, you are all aware of the damage that has been done to sport and commercial fishing in many areas in Ontario due to discharges of mercury and its compounds from certain segments of industry.

Many of these conflicts are not always apparent as those mentioned above. Industry sometimes prefer to absorb the additional costs for process water treatment rather than pursue more vigorous action with the upstream industrial polluter, and we suspect that some commercial fishermen have settled out of court for loss of revenue from poor catches through industrial pollution. However, most water-use conflicts can be adequately resolved by the polluter implementing an adequate effluent treatment and control program to safeguard water quality in the receiving waters.

In some instances, the technology is not adequately developed to deal with pollution problems. The discharge of high levels of dissolved salts from soda-ash plants is a significant input to the rising level of salinity in Lake Erie. In other instances, the technology is available to reduce pollution but the need for implementation has not been clearly demonstrated for environmental damage has not been proven. One such instance is the discharge of large quantities of heat from thermal electric generating stations to the Great Lakes system which may cause adverse localized effects. Cooling devices such as towers are possible methods of reducing heat inputs and have been built in other areas of the world; however, such towers have yet to be built in Ontario as no apparent use conflicts have been identified to the present time.

MUNICIPAL WATER SUPPLY

Municipal water supplies include water systems operated by municipalities, public utilities, commissions and commercial establishments where competent operation of the water supply system is normally provided.

The use of water by human beings for drinking and other domestic purposes is conceded generally to be the primary or most essential use of water. Such water may be given the primary procurement rights and is usually afforded the highest degree of sanitary protection, but other beneficial uses may have water quality requirements that are far more stringent in certain respects than those for drinking water. Many industrial processes, such as distilleries, cannot use without further treatment water that is suitable for domestic supplies; softened water from municipal systems can be detrimental for irrigation; and aquatic life in streams and lakes may be destroyed or inhibited by concentrations of metals such as copper and zinc that are permissible for domestic usage.

In recent times, sources of raw water have been deteriorating while municipalities are expected to produce a better and more uniform product for consumption. Fortunately, the technology exists to accomplish this. Since treatment processes exist which can convert almost any quality of raw water, it is necessary to define a commonly accepted treatment system which can produce a potable water at reasonable cost. For the purposes of the criteria which are listed, such a system is defined to consist of coagulation, flocculation, sedimentation and rapid sand filtration; also, the use of chemicals is restricted to the commonly used coagulants and chlorine for disinfection.

Two types of criteria have been established in Ontario, namely, Permissible Criteria and Desirable Criteria. 3 Waters meeting both of these criteria are acceptable for treatment by the defined process stated above. Waters meeting the Desirable Criteria provide for a greater margin of safety. Criteria published by the OWRC are compatible with those published by the Federal Department of National Health and Welfare. (4)

INDUSTRIAL WATER SUPPLY

The great demand for water by industry illustrates the extreme importance of this material. Water is used as an ingredient with other raw materials in the finished product, as a transporting medium, as a cleaning agent, as a coolant and as a source of steam in heating and power production.

The ideal quality of water required for industrial use varies widely for the many purposes to which water is put.

Needless to say, it is impossible to organize the quality requirements of the waters used for each of the many different industrial processes into a single set of standards. Such quality requirements differ far too much to allow any broad generalization or simplification. Within any industrial plant, water may have several functions, the quality requirements for which vary markedly. A brewery, for example, needs soft water for washing but can utilize hard water for brewing. Many industries require water of one quality for boiler feed, another quality for cooling, and a third for production processes.

Industry is generally willing to accept for most processes water that meets drinking water standards where water of higher quality is needed; also, industry recognizes that additional treatment is the responsibitity of the water user.

One characteristic is of primary importance for all industries, namely, the concentrations of the various constituents of the water should remain relatively constant. That the water is originally of poor quality for a particular industrial use is probably not as important, once a process is started and the difficulties created by the presence of undesirable constituents in water are eliminated, as having the quality remain constant. Short term variations in concentrations of substances in the process water require continued attention and added expense.

WATER QUALITY CRITERIA FOR SELECTED INDUSTRIAL USAGES

(a) Boiler Feed Water

The problem of make-up or feed water for boilers is common to almost all industries. Its importance and complexity has been the subject of much study. The presence of many substances in the raw water supply will render boiler feed water more difficult to treat or otherwise handle.

For boilers of very high pressure (1,000 psi or greater), all hardness must be removed dissolved oxygen should be less than 0.05 mg/1, and total dissolved solids should be as low as possible, preferably less than 0.5 mg/1. For such purposes, carefully distilled (or de-ionized) and de-aerated water is necessary, for no natural water would meet these conditions. Silica is especially troublesome, for it tends to form a hard scale in boilers and boiler tubes. Moreover, some of it carries over in the steam and forms troublesome deposits on the blades

of steam turbines. For high pressure boilers, dissolved silica should not exceed 0.2 mg/l although 1 to 5 mg/l can be tolerated at low pressures. Aluminum is troublesome, for it also tends to be deposited as scale on boiler tubes. Excessive sodium and/or potassium may contribute to the foaming of boiler water. Ideally, no ammonia should be present, for it is very damaging to copper parts. Finally, toxic boiler compounds should not be employed where steam is used directly in the preparation of food.

(b) Food Processing

One of the most important operations in commercial canning is thorough cleaning of the raw foods. The procedures of cleaning vary with the nature of the foods, but all raw foods must be freed of adhering soil, dried juices, insects, and chemical residues. This is accomplished by subjecting the raw foods to high-pressure water sprays while being conveyed on moving belts or passed through revolving screens. The product wash water may be fresh or reclaimed from an in-plant operation, but it must be of potable quality.

Washed raw products are transported to and from the various operations by means of belts, flumes, and pumping systems. This is a major use of water. Although the fresh water make-up must be of potable quality, recirculation is practised to reduce water intake. Chlorination is used to maintain recycled waters in a sanitary condition.

A third major use of water is for rinsing chemically peeled fruits and vegetables to remove excess peel and caustic residue. Water of potable quality must be used.

Green vegetables are immersed in hot water or exposed to live steam in blanching operations to inactivate enzymes and to wilt leafy vegetables to facilitate their filling into cans or jars. The blanch waters are recirculated, but make-up waters must be potable quality. Steam generation, representing about 15 percent of water intake, when used for blanching or injection into the product must be produced from potable waters, free of volatile or toxic compounds. Syrup, brine, or water used as a packing medium must be of high quality and free of chlorine.

After heat processing, the cans or jars are cooled with large volumes of potable water. This water must be chlorinated to prevent spoilage of the canned foods by microorganisms in the event that cooling water is aspirated during formation of a vacuum in the can.

A significant use of water is for transporting from the cannery, the inedible product, spillage, and trimmings that are discarded as waste.

A primary consideration for the quality of water used in food processing and especially in freezing processes is its bacterial content. Not only must such water be free of pathogens that may be transmitted to the consumer, but it must also be sterile with respect to saprophytic organisms that may cause spoilage. Many such organisms are destroyed in the canning process or remain dormant in frozen food, but their absence from the process water gives an added factor of safety.

The effects of chemical pollutants in the water differ for the various foods being processed. Substances that produce tastes, odours, colour, deposits, toughening, deterioration of quality or vitamin content, or other detrimental changes in the food are to be avoided. Chlorophenols in a process water, for example, have been reported to have produced tastes in the syrup of canned pears.

Hardness in the blanching water causes toughening of some vegetables such as dry beans or peas, coatings or deposits on others such as beets, and has no effect or may even be beneficial to some such as cream-style canned corn. Peas and snap beans that had been blanched before freezing with waters containing various concentrations of calcium and magnesium showed a greater loss of ascorbic acid and a greater gain of calcium as the hardness was increased. Compounds of iron, manganese, copper, other minerals, and organic matter have been named as the causes of taste, odour, colour and deposit difficulties. Copper is reported to decrease the shelf life of packaged foods, especially dairy and vegetable oil products. Apparently, flouride tends to concentrate in spaghetti, baked beans and cereal.

(c) <u>Cooling Water</u>

Cooling, or the transfer of heat, is a very common and important step in many industrial processes. Large volumes of water are used for cooling in various types of systems. The water may be circulated in a closed system, gaining heat as the product of process is cooled and losing heat in a tower or spray pond prior to recirculation. Alternatively, the water can be used first as a cooling agent and then either be wasted or be used in subsequent processes.

If a closed or recirculating system is used for cooling an industrial process, the only water added to the system is that needed largely to replace the evaporation and wind-blown or drift losses that occur in cooling towers and spray ponds. Corrosion, deposition of scale, delignification of wooden cooling towers, and the growth of microorganisms are four phenomena particularly detrimental to such cooling systems. A raw water introduced into such a recirculating system initially should have characteristics tending towards none of these phenomena. The make-up water too must be treated to conform with the desirable quality. The initial temperature of cooling water is of considerable importance and generally, the lower the initial temperature, the more desirable it is as a cooling water.

Deterioration of wood (delignification) is caused largely by sodium carbonate in the cooling water and a pH of 6.5 - 7.5 is recommended to afford a more favourable bicarbonate equilibrium. However, carbonates also give trouble by forming scales. Corrosive or aggressive waters also present serious problems and many additives such as hexametaphosphates, chromates, silicates exhibit corrosion-suppressing effects. The use of chlorine is well-known to suppress the growth of algae, slime-forming organisms and iron and sulphur-reducing bacteria.

(d) Pulp and Paper

The manufacture of pulp and paper is highly dependent upon an abundant supply of high-quality water. The major purposes for which water is used include the digestion or cooking of wood chips to make pulp, repeated washings of the cellulose pulp, transportation of the pulp and other constituents of paper in a thin slurry through preparatory processes and finally onto the paper machine, boiler feed and cooling. Water usage can vary from 2,000 gal./ton for insulating board production where a high degree of water re-use may be practised, up to 80,000 gal./ton for fine bleached kraft papers.

Suspended matter is undesirable in process waters because it decreases brightness, affects colours, interferes with texture and uniformity, clogs wire screens, and favours growth of slimes. Hardness gives difficulties by reacting with sizing compounds and causing the precipitation of calcium carbonate. It also tends to form scale on washing screens, the wire of paper machines, and similar equipment. Turbidity and colour can cause trouble in the finer grade products.

Dissolved gases in the process waters sometimes cause corrosion of the machinery while iron, manganese, silica and other organic matter are among other undesirable constituents of process waters.

The presence of microorganisms, such as bacteria, algae and fungi may lead to difficulties from the growths of slimes, slick spots on paper and the development of odours.

WATER QUALITY CONTROL - MANAGEMENT TECHNIQUES

To ensure that water quality requirements are maintained for all legitimate uses of a drainage basin, there are techniques which can be utilized which are described briefly below.

(1) Legislation

Enabling legislation is a prime necessity for water resource management programs. In the field of pollution control, history has shown that advances have been dependent on enforcement measures. Broad legislation with the power to promulgate regulations is required.

(2) Planning

Land use planning is important. It is necessary to develop compatible plans for the proper integration of industrial, recreational and municipal development without creating conflict, particularly with respect to use of the available water resources in the drainage basin. Without such plans, development is likely to be haphazard and optimum utilization of water restricted.

(3) Public Hearings

Mechanisms should be available whereby administrative bodies can obtain a measure of public opinion on the uses of water in a drainage basin and these opinions incorporated into the planning process. Also, the establishment of water quality standards for a drainage basin should be examined in a public forum by the persons living in the area. Those persons therefore have some input into deciding the type of environment they would like to live and work in.

(4) Drainage Basin Management Programs

Management of water resources on a drainage basin basis is a logical way of ensuring receiving water quality control and a number of programs are required to achieve this end. Water includes both surface and ground water supplies.

(a) Water Quality Studies - are necessary to determine the overall water quality in the basin. This includes physical and chemical composition of the water, analysis of the nature and composition of the bottom sediments, assimilative studies to estimate the capacity of the river to absorb biodegradable organic water, and hydrologic analysis of the river or lake with particular emphasis on low flow or low water periods.

(b) Biological Studies - define the biological condition of the watercourse. Phytoplankton, zooplankton, and bottom fauna studies are required. Both biological and water quality surveys on a river or lake define the zone of influence of pollution.

(c) Use Studies - there may be many uses of water in a drainage basin, perhaps for all the beneficial uses listed previously in this paper. Different segments of a river or lake may have a prime use which overshadows all others in that region and water quality standards should reflect that prime use.

(d) Water Quality Standards - promulgated to ensure that water quality requirements are maintained for specified uses in that part of the watershed. Standard setting appears to be the trend of the future. Public hearings may be involved in this procedure.

(e) Water Quality Monitoring Programs - suitable quality monitoring programs are required to ensure that quality is being maintained in the river or lake. This responsibility generally falls on the shoulders of government agencies. Contingency and Spill Corrective Action Plans should be developed for prompt implementation in drainage basins particularly where industrial or shipping activities are intensive.

(5) Effluent Control Programs

All sources of wastes to a drainage basin, whether municipal, industrial or storm water outlets, should be located and surveyed. Flows should be measured, pertinent waste characteristics identified and measured and input loadings calculated.

It should be the responsibility of industry and municipalities to monitor their own waste inputs and to submit data on a regular basis to the regulatory agency. Bioassay studies to determine toxicity of effluents to selected organisms are useful.

Where problems exist, appropriate effluent control programs should be developed. Treatment systems should be designed to give the type of effluent quality which would not deteriorate water quality in the receiving stream as designated by the water quality standards. Mixing zones should be established for each outfall and zones of passage in rivers for fish delineated. An appropriate reserve of the river or lake capacity should be set aside for future development and also to serve as a safety factor.

This section is not meant to be all inclusive, however it is intended to show the variety of management techniques required to maintain water quality for various uses.

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WATER MANAGEMENT IN AN URBAN AREA

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WATER MANAGEMENT IN AN URBAN AREA

Introduction - Long-Range Planning

The location of a growing urban area is dependent on many factors but none more important than the quality and quantity of the water resource available to that area. Water, or the lack of it, is a significant limiting factor whether it has to do with the adequacy of the water supply for diverse municipal purposes including industrial usage, or the capacity of the receiving body of water, such as a river or lake, to dilute, carry away and assimilate the resulting treated wastes. Therefore, wise long-range planning is essential to developing satisfactory water management programs in urban areas, particularly in major centres such as Metropolitan Toronto, which are experiencing above-average population growth rates. Such water management programs include the development and maintenance of a hygienically safe, good quality water supply for all municipal purposes, proper treatment of wastes to safeguard the quality of receiving waters for multiple uses, implementation of satisfactory flood control measures where applicable, and development of drainage basins of rivers and lakes in and around the urban area for optimal recreational and aesthetic benefits to the general public.

Legislation and Water Management

The Ontario Water Resources Commission has been vested by the Legislature with the necessary powers to manage the water resources of the Province of Ontario. Through the OWRC Act, the Commission has the power to do many things including the following:

(a) to control and regulate the collection, production, treatment, storage, transmission, distribution and use of water for public purposes;

(b) to construct, acquire, provide, operate and maintain water works and to develop and make available supplies of water to municipalities and persons;

(c) to construct, acquire, provide, operate and maintain sewage works and to receive, treat and dispose of sewage delivered by municipalities and persons; and

(d) to make agreements with any one or more municipalities or persons with respect to a supply of water or the

reception, treatment and disposal of sewage.

It is obvious then, that many of the water management programs in an urban area fall under the jurisdiction of the OWRC. However, municipalities do have the authority to develop and administer their own water and sewage services as laid out in The Municipal Act. For example, Metropolitan Toronto plans, develops and constructs its own water and sewage services required by that area; however, all such works must be approved by the OWRC which is also the overriding regulatory body with respect to the quality of effluents discharged to the Lake Ontario drainage basin. In the newly-created regional municipality of Ottawa-Carlton, the OWRC has agreed to turn over its sewage facilities to the municipality after strong pleas by local government officials that they be allowed to run their own affairs. On the other hand, the Commission, through formal agreement with five municipalities and townships, is planning, building and operating water and sewage facilities to serve the vast area of Peel County which is immediately west of Metropolitan Toronto. This immense regional scheme, capitalized at approximately $88 million is geared to meet the rapidly growing demands of centres like Brampton and Mississauga in the foreseeable future.

Water Supply

As noted above, one of the prime requisites for an urban area is an adequate supply of good quality water. Ontario has an abundance of water. It borders four of the five Great Lakes which constitute approximately one-fifth of the world's fresh water resources, and in addition is criss-crossed by numerous rivers and lakes, both large and small. Even so, in certain areas such as Southwestern Ontario, the growth of cities and towns like Kitchener-Waterloo, Guelph, London and Chatham has placed intolerable strains on existing surface and groundwater supplies. For example, intensive water conservation programs on the Grand River, such as the building of dams to maintain adequate flows on an all-year round basis, have aided considerably in the utilization of this river as a source of municipal and industrial water supply. Also, groundwater aquifers are an important source of water supply to other centres such as Guelph and Galt and much has been done to find and develop new aquifers. However, water levels in wells have been dropping steadily in recent years due to increased

demands. It is safe to say that continued growth in these urban centres is closely tied to the future availability of water. One possible solution to this type of problem is the building of water pipelines from the Great Lakes to supply these inland urban centres. The OWRC has entered this field and the London and St. Thomas pipelines are examples of the Commission's role as a water utility, where the works are totally financed, built and operated by the Province through the OWRC and water is sold to the municipalities (or industries) at cost. This operation is not unlike that of Ontario Hydro in the electrical power generating field.

The quality of water in Ontario for municipal usage is generally good, although water treatment methods may vary depending on the location, size and source of the water supply. Water treatment practice in Ontario commonly consists of sedimentation and/or filtration to remove particulate matter, followed by chlorination for bacterial disinfection. Some urban areas fluoridate their water as an aid to dental health in children.

The production and sale of potable water for urban centres generally rests with the municipality. The Commission can and does enter the picture if financing is required by the municipality. There are several ways of financing both water and sewage plants and the OWRC may enter into an agreement to operate these plants for the municipality.

Primarily because of public health reasons, the OWRC has the authority to, and does, inspect all water treatment plants in the Province on a regular basis to check that suitable treatment processes, usually chlorination, are being operated at all times for the proper disinfection of water. The record shows that the incidence of dangerous water borne diseases such as typhoid has been practically eliminated in Ontario.

Waste Treatment

The treatment of wastes generated in an urban area is a complex problem involving the air, water and soil. In this paper, reference is made only to liquid wastes. Once again, long-range planning is essential so that treatment facilities can be built and operated on schedule to take care of projected increases in population and industrialization. Only in this way can surrounding waterways be safe-

guarded from the many undesirable effects of pollution. In Ontario, legal measures can be applied by the OWRC to municipalities to ensure that proper planning is effected.

As stated previousl;, many urban centres are located on a body of water, be it a river or lake. The location of the waste treatment plant is important and on rivers, the plant is usually downstream of the city and below the location of the water supply intake. With respect to lakes, the effluent from the sewage treatment plant is usually transported by means of a submerged pipe and discharged at a suitable distance into the lake so that adequate dispersion can be obtained to minimize any potential adverse effects on water quality.

In many urban centres, rivers run through the built-up area as for example, the Don and Humber Rivers in Metropolitan Toronto. Many of these rivers are small and experience drought or minimal flow conditions during certain months of the year with the result that they have limited capacities to assimilate treated wastewaters. Pollution of such rivers can be minimized by not building sewage treatment plants at the head waters of these rivers to serve other communities upstream of the urban area. As a policy, the OWRC favours the translocation of wastes in trunk sewers to locations on the lake front for treatment and proper disposal into the larger receiving body of water.

Municipal sewage treatment plants in Ontario generally serve to remove gross suspended solids from the wastes, oxidize organic matter by biological methods to harmless end-products and sterilize the final effluent by chlorination to destroy any pathogenic organisms which may be present. The removal of nutrients such as nitrogen and more particularly phosphorus is being studied actively by the OWRC and treatment systems have already been implemented in a few locations. This latter treatment process is essential in many areas if rapid eutrophication of some of Ontario's most important lakes, as evidenced by massive algal blooms, is to be prevented.

Urban areas generally attract and encourage industrial development. Metropolitan Toronto is an excellent example of a heavily industrialized area. Where proper treatment plants are available, the OWRC encourages the discharge of industrial wastes to the municipal sanitary

sewers provided the wastes are treatable by the processes used at the municipal plant and there is adequate capacity at the treatment plant. Often, suitable pretreatment of certain types of wastes is required at the industry before discharge to the municipal sewer system, for example, pretreatment for removal of toxic heavy metals from plating installations. The policy of advocating the discharge of industrial wastes to municipal sewers where feasible, results in fewer treatment plants being built and decreases the proliferation of sewage works in a built-up area. This policy usually results in better economies for the industries concerned to the overall benefit of the whole municipality.

The discharge of industrial wastes to municipal sanitary sewer systems should be regulated by the enactment of suitable sewer-use by-laws. These by-laws should be enforced by the municipality and agreements can be made with industries with over-strength wastes through appropriate surcharging costs to discharge to the municipal system. The OWRC offers a technical advisory service to municipalities on the matter of sewer-use by-laws.

Combined Sewers and Storm Runoff

One of the major problems in many urban areas is the combined sewer, that is, a sewer which transports both sanitary sewage and storm runoff. Where combined sewers exist, the capacity of these sewers are often exceeded when precipitation occurs and pumping stations overflow to the nearest creek or stream. This means that quantities of sewage in a diluted form are discharged untreated to receiving watercourses. The capacity of the sewage treatment plant is also taxed under such conditions and bypassing around the plant, or use of only a portion of the plant (primary section), is necessary. Combined sewers were cheaper to install in the old days, but this practice is not permitted any longer in the Province by the OWRC. Where combined sewers do exist, it is a major and costly construction job to correct the situation. Metropolitan Toronto is currently on a program of sewer separation which is expected to last for 25 years at an estimated cost in excess of $200 million.

Storm runoff from urban areas constitute a significant source of pollution depositing silt,oils, organic debris such as leaves and branches into nearby watercourses.

During the winter months, hundreds of tons of salt used on roads in the Toronto area end up in the streams and eventually reach Lake Ontario. The maintenance of the natural cleanliness of a stream meandering through a built-up area, even with all industrial and municipal discharges eliminated from the stream, such as the Don River in Metropolitan Toronto, is difficult simply because of storm runoff. Accelerated erosion and mud and silt in runoff from construction areas together with the other pollutants mentioned above, degrades water quality and usually requires the stream to be dredged on a regular basis.

Finally, because of the hundreds of square miles of concrete and asphalt and other impermeable materials placed over the ground in an urban area, retention and seepage of water into the ground is minimized thus preventing groundwater recharge. Storm runoff goes immediately to the nearest ditch or stream and flows away. Thus, because of the lack of recharge, streams in urban areas tend to dry up - an unfortunate effect of urbanization.

Land Use Planning and Conservation

The rivers, streams and lakes in and around an urban area are valuable natural resources. Proper land use planning and conservation practices should be encouraged to develop the potential for recreational pursuits and general aesthetics for the benefit of the community.

The Metropolitan Toronto and Region Conservation Authority pursues many programs to enhance the usefulness and beauty of the watercourses in this area. Flood plains of the various major rivers are being bought and placed in public ownership to be used as parklands. Flood control structures, retardation dams and reservoirs are built on major watercourses to ensure minimum flows in the river valleys during dry periods as well as to eliminate the possibility of future severe flooding. The Authority develops conservation areas at the head waters of these rivers beyond the boundaries of Metro for recreational purposes including fishing, swimming and other outdoor activities.

Summary

Water management in an urban area is a complex matter requiring long-range planning to meet the demands of projected growth of population and industrialization

together with imaginative land use planning and conservation policies. All levels of government have a role to play. The costs can be high but the overall benefits to the community are unquestioned.

AGRICULTURE AND WATER POLLUTION

IN

ONTARIO

by:

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Introduction

Quality of the environment has always been of vital concern to every segment of society, but never before has it received such public awareness as at present.

Environmental pollution is, in effect, the unfavorable alteration of our surroundings through direct or indirect effects on the pristine quality of our air, soil and water resources, influenced primarily by man's activities. Programs for improving environmental quality must aim at preventing further deterioration and at restoring the quality to a socio-economically acceptable level. Some pollution is inevitable but it must be kept within well defined degrees, in many cases, not yet determined.

In the past we have concentrated most of our effort on controlling pollution from domestic and industrial waste sources. Needless to say, such wastes still contribute greatly, as a whole to water and environmental pollution but their control is now within our technology.

Pollution from agricultural operations is a relatively new concept and there is a sad lack of knowledge concerning the contribution of its various aspects. Our present concern over agricultural operations stems from the fact that they do present an immense and relatively uninvestigated pollution potential and as such deserve our immediate attention. Agricultural pollution must be considered together with municipal, industrial, and other sources of pollution in developing an integrated effort for improving the deteriorating quality of our environment.

For purposes of this paper, pollution from agricultural operations have been divided into 6 basic categories and each will be dealt with under a separate heading as listed below. Although this report is primarily concerned with water pollution any measure carried out to protect the water environment will generally also affect the air and soil environments.

The 6 basic categories of agricultural operations which contribute to water pollution are as follows:

(a) Farm animal wastes,
(b) Wastes from industrial processing of raw agricultural products,
(c) Sediment,
(d) Commercial Fertilizers,
(e) Pesticides,
(f) Miscellaneous minor sources.

Farm Animal Wastes

Farm animal wastes in Ontario, probably exceed wastes from any other segment of our economy. Over 5.5 million head of livestock at a value of some $700 million and a total poultry population of some 31 million at a value of over $50 million produce approximately 130 million pounds of manure per day with the strength equivalent to the sewage of some 30 million people or about 4 times the present population of Ontario.

Until recently, farms have not been thought of as serious sources of pollution because the diverse nature of their activities and comparatively small scale and isolation provided protection against such problems. Modern farming practices, however, are tending to eliminate these safeguards and it is now imperative that these industries comply with the generally accepted standards of pollution control applied to other agricultural industries.

The actual changes within the farming industry which have brought about a need for concern for farm animal waste management are:

(a) Specialization of farm operations have increased the concentration of manure production,

(b) Confinement housing has led to a further concentration of manure and significant changes in manure characteristics, and in particular, the trend towards liquid manure handling systems,

(c) Cheaper and more manageable commercial fertilizers have reduced the demand for manure as a fertilizer, and

(d) Urban sprawl and farm area encroachment have brought more people into close contact with the environmental problems associated with farming operations.

Confinement housing of livestock and poultry is perhaps the major factor in the creation of an immense manure disposal problem. In the confinement method, food and water are brought to the animals and no longer do they

drop their manure on pastures where it can be absorbed naturally. Instead, the wastes must be collected, stored and then disposed of. In most cases application of animal wastes to crop lands affords the optimum method of disposal.

The livestock farmer, however, is generally in the animal business, not crop farming. He relies upon commercially available food supplements for a considerable portion of his feeding requirements, and thus, he frequently does not have adequate land of his own for the effective disposal of his manure. The crop farmer, on the other hand usually feels that he can buy and apply chemical fertilizers more cheaply than he can use free animal manure.

In Ontario, we are fortunate to have adequate land for the effective disposal of farm animal wastes. As mentioned the problem stems from the fact that the large operator may have to rely on his neighbours to provide this land and also that in Ontario there is an extensive winter period during which manures can not be successfully applied to the land. Manures must therefore be stored for periods of up to six months. Conventional methods of manure storage cause the production of very foul odours, especially where pig manure is concerned, making spring application a very unpopular task and not one which a crop farmer is willing to undertake.

Successful management of farm animal waste in Ontario will depend largely upon two conditions:

1) that farmers, especially crop farmers, can be convinced of the fertilizing value of manures, and

2) that economical means of managing manures and controlling odours during storage and land application be developed to allow for proper application of the wastes to farmland.

Pollution Potential of Farm Animal Wastes

The treatment and disposal of animal wastes are complicated problems for agriculture. Compared to municipal sewage, farm animal wastes are extremely highly concentrated with organic and inorganic pollutants. As such, it is not economically feasible to purify these wastes in treatment plants as are municipal and many industrial wastes. Land application appears to be the only practical method of manure disposal present. In such disposal practices, proper

management is essential to guard against pollution of our air, soil and water environment.

Because of the vast quantities involved, farm animal wastes must be considered as a threat to the environment, not so much because of present pollution which can be attributed to them, but because of their massive pollution potential.

Even though current literature suggests that agriculture as a whole is only a minor contributor of environmental pollution when compared to industrial and municipal wastes, animal wastes are causing isolated cases of air and especially water pollution which, to a particular stream system, can be as detrimental as industrial waste pollution is to the Detroit River.

Water Pollution Aspects:

1) BOD: The Biochemical oxygen demand (BOD) of animal manure is extremely high and it is also high in the runoff from feedlots and in effluent from partially treated wastes. The BOD of grab samples from manure- holding tanks and pits may be 100 times that of municipal sewage; the BOD of runoff from feedlots, 10 to 100 times; and the BOD of partially treated waste effluent, 10 times. Such high-oxygen demanding wastes upon entering streams cause oxygen depletion resulting in fish kills and long-term ecological changes. They also can affect the esthetic value of streams and lakes and render them unattractive as recreational waters.

2) Nitrates: Because of the high nitrogen content of manures, ground water contamination by nitrates from animal wastes must also be considered. Excessive concentration (<45 ppm) in ground water used for drinking may be biologically converted to nitrates in the digestive system and can cause the birth of "blue babies" in both livestock and humans.

3) Pathogenic Organisms: Organisms pathogenic to people, animals, and poultry may be present in the manure from farm animals and may be transmitted in surface and subsurface waters. Any water that has been in contact with animal wastes must therefore be considered as potentially dangerous to the health of livestock and humans.

4) Eutrophication: Eutrophication is the process of enrichment of lakes by nutrients and has been attributed primarily to their increase in nitrogen, phosphorous and

carbon. Farm animal wastes contain all of the macro and micro-nutrients essential to the growth of plant life and could play an important role in the increasing intensity and frequency of algae blooms on many of our lakes and rivers. Except in isolated cases, only nitrogen has been considered as a potential major nutrient pollutant from agricultural operations because of the ease at which it is transported through the soil.

More will be said concerning the nutrient pollution of water in a subsequent section on Commercial Fertilizers.

Manure Management Practices to Reduce Environmental Pollution

Manure has a significant value as a fertilizer and therefore should be utilized as such wherever practical. It should be used to provide the main fertilizer requirement for crop production with the addition of commercial fertilizers only as required. However, to eliminate ground surface water pollution from manure, the application rate and interval must be carefully adjusted.

Under Ontario's climatic conditions, this necessitates storage of manures over the winter period with storage requirements such to provide up to 6-months capacity during periods when the land is frozen, muddy or snow-covered. Application at these times would invariably result in considerable runoff.

Past manure storage methods have involved the use of manure pits, lagoons and other forms of holding tanks. Such systems all act as anaerobic digestion units and are characterized by foul odours (air pollution) during storage and particularly at the time of emptying, especially where swine and poultry manures are concerned. If field spreading is to be made effective, these odours must be controlled to a minimum.

Although some degree of odour associated with modern farming industries is inevitable, different processes have been and are being used to control the odours from farm manures during storage and at the time of field application and such is the basis of most of the research that is currently being carried out on farm animal waste disposal in Ontario.

Processes used to control odours may be divided into two main categories:

(a) chemical, and (b) aeration.

a) <u>Chemical Processes</u>:

Hydrated lime, chlorine and deodorizing and maskinto compounds have been added to liquid manures to suppress or prevent the production of objectionable odours. None of these chemicals has been proven to be entirely satisfactory, however, and all are relatively expensive.

b) <u>Aeration Processes</u>:

Aeration processes, on the other hand, have been found quite satisfactory. As the object here is odour control, only that small amount of air needed to discourage anaerobic bacteria from predominating is required. Any method of mixing adequate air into the tank contents can effectively control odours and therefore, there are several diversified methods available. Methods practiced in Ontario include the oxidation ditch process, diffused air processes, and air aspirator processes.

Wastes from Industrial Processing of Raw Agricultural Products

The processing of agricultural products results in major problems in air and water pollution control and solid-waste management. Liquid processing wastes are invariably of very high strength and require high degrees of treatment before they can be safely discharged to receiving waters.

The accumulation of solid wastes from the processing of crop and animal products is also a major pollution problem. The culls, peelings, pits, trimmings, screenings, sludge, and other solid wastes produced are characteristic of each product and process and, therefore, each generally requires a different method of treatment or disposal. Many of these solid wastes pose troublesome fly and odour control problems because of their high content of readily decomposable organic matter. Also because of this characteristic they must be disposed of in such a manner so as to prevent them from entering a watercourse. To further augment the problems, the production of

such wastes is normally seasonal, requiring only the periodic use of disposal facilities making it difficult to justify their cost.

Although effective waste treatment processes have been developed for most of the agricultural product processing industries, much can usually be done within the process operation itself to reduce the cost and increase the effectiveness of such treatment processes.

Efficient separation and removal of solid wastes from the processing stream is an important factor in minimizing the strength of the process waste. In all the animal processing industries, 30 to 35 percent of the live animal weight must be converted to useful products or removed.

Again, disposal of processing wastes to the land should be practiced wherever possible whether liquid or solid. Liquid wastes may be used for irrigation and fertilization purposes. High degrees of treatment are required before discharge to receiving streams.

Direct research is required to reduce the quantity of waste product and may be directed towards several disciplines. The modernization of harvesting and processing could substantially reduce wastes from these operations. More effort should be put into byproduct recovery and utilization. Many processing wastes may be economically converted for use in livestock feeds. Continued research may also result in changes to produce agricultural raw materials that are more readily processed with less wastage.

Sediment

Volume-wise, sediment resulting from the erosion of land is perhaps the greatest contributor to the pollution of surface waters affecting both the quality of the watershed and its physical characteristics. Harmful effects may therefore, be physical, chemical, or biological.

Sediment is solid material, organic and inorganic, and occurs as a result of (a) sheet erosion by soil runoff; (b) stream bank erosion; (c) flood erosion by scouring of floodplain land; and (d) erosion from road building and other construction activities.

Perhaps the major source of sediment due to agricultural operations is the erosion of stream banks resulting from the grazing of cattle or the cultivation of fields too close to the stream edge. Farmers are therefore encouraged to place the land adjacent to streams under grassland and to consider the fencing of stream banks and if necessary, providing well defined crossing or watering places at points least subject to erosion.

Soil erosion and its effects are damaging many times over: there is the irreparable loss of soil; sediments not only contribute to suspended solids pollution, but also to the dissolved solids problem; and, sediment frequently adversely affects the area where it comes to rest and is very costly to remove. Flood-borne sediment deposited on productive flood plains may damage crops and reduce the productivity of soils. Drainage and irrigation ditches clogged with sediment do not function properly and require costly maintenance.

Stabilization of the sediment source by proper land management and erosion control measures is the most direct and usually the most satisfactory approach to handling most sediment problems. Such erosion control practices conserve land and vegetation resources while reducing sediment yield.

Direct surface soil runoff may be best reduced by providing suitable crop rotation through the inclusion of hay, or pasture in the cropping sequence. Such practices as mulching, strip-cropping, and contour cultivation have been shown to be highly effective in reducing soil erosion on farmland.

Commercial Fertilizers

As inorganic chemicals are essential for the mineral nutrition of plants, such nutrient materials although naturally available in agricultural lands are annually replenished to highly productive crop lands. Such replenishment is normally accomplished through the application of

commercial fertilizers at different stages of crop development. Included in the nutritional requirements of plants are the major fertilizer elements, nitrogen, phosphorus and potassium; the secondary elements, calcium, magnesium and sulphur; and the micro-nutrients, iron, copper, boron, manganese and zinc. All these elements are normal constituents of fertile soils and are vital at different concentration levels to the production of plant growth.

Nutrients in surface waters may become contaminents in that they contribute to undesirable growth of aquatic plants which may greatly deteriorate the economic and aesthetic qualities of a body of water. Nitrogen and phosphorus are the two elements generally limiting to algal growth in natural water. Farmland, barnyard and feedlot runoff and leachate can be major contributors of plant nutrients.

The increased demands for nitrogen imposed by higher yielding crop varieties and improved farming practices have resulted in the increased application of nitrogen fertilizers in the past few years. In 1968, the annual consumption in Ontario exceeded 100,000 tons of nitrogen. Its useage is expected to continue to rise.

As nitrogen moves freely through the soil, water pollution problems may arise (1) if available nitrogen exceeds crop requirements or (2) if excessive rainfall occurs with subsequent leaching to ground water.

Phosphorus is another major nutrient, essential to all forms of life-field as well as aquatic vegetation. Small increases in phosphorus concentrations of natural waters stimulate the growth of blue-green algae and other plant forms.

There are several sources of phosphorus which, in recent years, have considerably raised the phosphorus content of our natural waters until aquatic growth problems are now abundant; the major contributors being municipal wastes, food processing wastes and farm animal wastes. Also of considerable importance as a source of phosphorus because of the large areas involved is the runoff from fertilized agricultural land. Most of the applied phosphorus fertilizer becomes so strongly tied up by clay particles that almost none is transported through the soil by water percolation. Thus repeated fertilization can build up the level of total phosphorus in the upper layers of soils to considerably high levels. Phosphorus is therefore, frequently carried on eroded soil particles into streams and

surface water systems when such soil erosion occurs. Sediment laden water may contain as much as 10mg/l of total phosphorus.

The main pathway of phosphorus into water supplies from fertilizers is through soil erosion, while that of nitrogen is through ground water intrusion. The best ways to reduce these sources of pollution are therefore, to guard against over-fertilization and to reduce watershed and stream bank erosion.

Considerable research is still required to further define the causes and effects of lake fertilization due to commercial fertilizer application. A better understanding of the behavior and fate of applied nitrogen, phosphorus and other plant nutrients in relation to soil type and plant crop will aid in establishing guidelines to minimize water pollution. Further studies are required to minimize runoff and percolation of nutrients by using them more effectively and efficiently. We also require a further understanding of the effects of nutrients on algae and noxious water plants.

Pesticides

Pest control agents, along with fertilizers and improved cultural techniques have made possible the production of an increasing amount of food of superior quality and have greatly enhanced the Canadian standard of living. Pest control, through the eradication of many insect-borne diseases, has also permitted a more pleasant and healthful utilization of our environment.

Pesticides become pollutants when they, their metabolites, or their degradation products linger in the environment after the desired purpose has been accomplished or when they reach some part of the environment other than that area intended. Pesticides vary on the amount of pollution they produce, depending upon their persistence, upon the relative severity of their persistence, and also upon the relative severity of their toxic effects.

Pesticides are used for many purposes in addition to the protection of crops and livestock from insects, diseases, weeds, and other pests. Therefore, their presence in the environment is in no way limited to agricultural contributions. Agriculture, however, is a major user of pesticides and almost all agricultural by-products and wastes contain small amounts of pesticides.

Inadvertent or accidental contamination of the environment may occur during and after application of pesticides to crops and crop lands. Inadvertent application to streams and ponds or to land areas not intended to be treated has occurred, and although this source can be minimized through adequate precautions it will not be completely eliminated. Air drift of pesticides also occurs, especially if the application is by aircraft although drift from other methods of application may also be considerable. Again this source can be minimized but not completely eliminated.

Erosion resulting from heavy rains or from irrigation is a source of movement of pesticides from treated to untreated areas, and into both surface and underground waters. Minute amounts of pesticides may also be carried in solution in water.

In the aquatic environment an accumulative concentration of pesticides occurs. Certain lower forms of aquatic food chains may accumulate the chlorinated hydrocarbon pesticides (ie DDT) present in water in almost infinitesimal amounts. Some fish use the micro flora and fauna as a major source of food and thus, may accumulate high levels of certain pesticides or their metabolites in their fat. Similar concentration may occur in certain birds and animals.

The most important problem regarding pesticides as environmental pollutants is therefore, the evaluation of their long-term ecological significance. Reliable information as to whether or not present environmental levels are increasing is required. It is also essential to determine whether long-term exposure to sublethal levels of pesticides may produce ecological changes, either genetic or environmental which will affect man's welfare.

The development of integrated control programs involving the combined use of chemical, cultural, physical, and biological methodsare required to reduce the dangers of any single control element. Such methods are now applied in the control of several economically important insects.

Significant amounts of pesticides are transported in air from their place of application and this movement may be the principal method of dispersion over wide areas. The means to reduce or prevent this is imperative.

The problem of the disposal of empty pesticide containers is also very acute and until a suitable solution is found such containers will be a continued source of pollution of the environment.

Miscellaneous Minor Sources

There are several other minor sources of water and environmental pollution which do not fit in any of the above categories; these include crop residues, infectious agents, toxics and allergens.

Residues from crops and orchards are frequently disposed of by burning and are thus a source of smoke and other air pollutants but contribute to water pollution generally only if the ashes are allowed to wash into a waterway. Crop residues themselves can become reservoirs of plant diseases and other pests. Accumulations of decaying plants such as pea vines in fields often cause obnoxious odours.

Infectious agents, harmful to plants, animals and humans may be transported in our surface and subsurface waters. These agents may arise from animal wastes, processing wastes or crop wastes and consideration must be given to the control of their movement.

Materials toxic to plants and animals may also be transported in surface and ground water. The nature and sources of such toxins are wide and varied but they may have significant effects on the environment. Plant allergens may also be carried in waters.

Summary

In recent years, the public has become much more aware of, and concerned about, the quality of the environment with greater demands being made to "clean up" our air, water and soil resources. No one, however, has yet decided how clean we want the environment or how much we are willing to spend to clean it up and keep it clean.

The desired quality or cleanliness of a water shed may vary with different situations. For example, water for fishing purposes does not have to be, in fact preferably should

not be, as pure as water for drinking purposes. For these reasons, rigid water quality objections are highly impractical, instead they should be designed specifically for each particular watershed taking into consideration, watershed geography, land use practices, water use requirements and future developments.

The effective management of our water resources depends on the development of a broad sense of economic and social responsibility and a more thorough knowledge of the short-term and long-term effects of pollutants. Socio-economic considerations will define the specific economic and cultural needs and dictate water use requirements. A compromise can then be established of allowable pollution from industrial, municipal and agricultural sources to protect the needs of the area involved.

Like most other of man's activities, agriculture contributes to the pollution problem and that contribution is a significant one. Proper waste management practices can greatly reduce the farm animal waste source of water pollution; improved land use practices can greatly reduce the sediment and commercial fertilizer sources of water pollution; provision for adequate treatment and disposal of agricultural processing wastes will likewise reduce that source of pollution; and, the proper application of pesticides and herbicides will reduce the adverse effects of these materials on the environment.

Admittedly, there is still much to be learned about the science and technology of controlling pollution from agricultural operations. As with all other forms of pollution, however, the problem can be attributed in large measure to the failure of making effective use of what is already known.

THE COTTAGE COUNTRY FIGHT

TO

SAVE OUR RECREATIONAL LAKES

by

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ONTARIO'S PRICELESS HERITAGE of thousands of lakes scattered throughout our vacation areas is currently under pressure from a relentless onslaught of cottage development, arising from our present affluence and society's related love affair with the great outdoors.

Beset by the complexities and frustrations of urban existence, thousands have turned to cottaging experience as a Utopian Mecca, providing some respite of quiet, solitude and relaxation from the heady pace of modern living.

With the advent of the snowmobile and its amazing rise to popularity, new trends have rapidly evolved in the development of winterized structures and increased year-round use of cottage properties. In addition, significant numbers of people reaching their retirement years are now establishing permanent homes at 'the lake'. For these and undoubtedly other reasons, Ontario's present cottage density has grown to approximately 200,000 and is anticipated to increase at the rate of an additional 10-to 15,000 units each year.

The burgeoning population pressure in cottage country resulting from these many factors is cause for just concern for the future of our recreational lakes. The purpose of this article is to consider the nature of the stresses affecting our lakes, to comment on evaluation programs now underway, to highlight some of the current limitations which aggravate the potential seriousness of water pollution and to consider how cottagers can contribute to offsetting the threat of declining water quality.

BACTERIOLOGICAL WATER QUALITY

For many years cottagers have generally equated water quality with suitability or non-suitability from the standpoint of bacteriological evaluation. A number of cottagers' associations have undertaken sampling programs over the years in co-operation with health authorities to pinpoint problem areas and to focus attention on the need for remedial action.

Unquestionably, localized bacteriological problems in recreational lakes associated with inadequate or malfunctioning cottage waste treatment systems are still all too frequent. The monumental task of isolating and investi-

gating specific cottage pollution sources as well as the responsibility for inspections of new septic tank installations, have strained the capabilities of under-staffed local health units. Improved programs have been formulated to tighten controls on new cottage subdivision developments and to strengthen inspection capabilities for existing cottages, which will be discussed in a later section.

Changes in approved criteria for bacteriological quality were introduced by the Ontario Water Resources Commission for Ontario waters on June of 1970. Under these criteria, water used for body contact recreational activities can be considered impaired when the following values are exceeded (based on geometric mean densities):

Coliforms	1000 per 100 ml.
Fecal coliforms	100 per 100 ml.
Enterococci	20 per 100 ml.

Microbiological evaluations for recreational waters should be based on a series of at least ten samples per month, including samples collected during week-end periods.

Separate criteria are in force for private water supplies for individual dwellings and cottages. Water used at cottages must be of such quality that it can be used in the raw state or be made acceptable for use with a minimum of treatment, limited to disinfection, filtration and/or softening,

Bacteriological contamination is the type of pollution which is undoubtedly of most direct significance to the cottager. However, this type of pollution can be readily identified and through the implementation of proper controls a relatively spontaneous return to satisfactory water quality conditions can be achieved. Thus, it is fitting that the main thrust of this presentation should be devoted to another water quality problem which is not so well understood and which has far more serious long term implications.

EUTROPHICATION

It is only within recent years that the more lasting effects of a type of pollution best described as nutrient enrichment have become clearly recognized. This phenomenon, scientifically known as eutrophication, is associated with

sedimentation and increases in the dissolved mineral content of a lake - specifically substances such as phosphates, nitrates, carbonates, and numerous trace elements - increases which occur as a result of precipitation, land run-off and percolation of soil water to the lake basin.

Higher concentrations of these dissolved materials cause the water to become progressively more fertile and productive, stimulating the development of microscopic free-floating plants called phytoplankton, sometimes referred to as algae.

Algae are normal inhabitants of virtually all surface waters and fulfill an essential role in maintaining a balanced condition in the aquatic environment. They not only provide the entire nutritional base for a complex aquatic food web that includes the production of game and commercial fish species, but they release oxygen to the water which is vital to the respiration of fish and all other forms of aquatic life.

The natural development of algae in a lake is regulated not only by nutritional factors, as previously mentioned, but by environmental factors such as temperature, the intensity and duration of illumination (sunlight) and by physical factors such as size, depth and shape of the lake basin.

Thus the corresponding rates of eutrophication in different lakes are determined by varying combinations of extrinsic and intrinsic features.

All lakes, even the largest and deepest, are transitory bodies of water undergoing this gradual process of change from youth to maturity to old age, or, in limnological terms, from oligotrophy to mesotrophy to eutrophy. Progressing even further, death of a lake can be equated as the onset of the 'swamp' condition.

In small, shallow lake basins this entire process may have occurred in some cases within a single century following the glacial retreat; in other cases the process is well advanced, and still going on, and in many larger, deeper lakes removed from civilization, significant changes can only be measured on a geologic time scale, i.e. thousands of millions of years.

MAJOR DIFFERENCES IN ONTARIO LAKES

Lakes surrounded by granitic bedrock and the sparse infertile soils of the Precambrian Shield which covers Muskoka, Haliburton and areas farther north are characterized by low rates of algal production and consequently age less rapidly than lakes surrounded by the deeper, richer soils of Southern Ontario.

Correspondingly, 'nutrient - poor' lakes on the 'Shield' having moderate to extreme depths, generally support a relatively low production of cold water fish species such as lake trout, whitefise and herring. They are characteristically clear and well-suited to swimming and other water-oriented recreational pursuits. Also the deeper waters are well supplied with oxygen throughout the year.

The latter condition relates to the low algal production and concomitant lack of any significant oxygen depletion associated with the decomposition of algae at the lake bottom.

Alternatively, fertile lakes, such as the Kawarthas, are more turbid owing to the increased phytoplankton production and presence of suspended particulate matter. They contain substantial growth beds of submergent leafy vegetation such as water milfoil, elodea, coontail and pondweeds and produce higher yields of warm-water species such as walleye and bass.

Adequate levels of dissolved oxygen are generally present from surface to bottom since these lakes are shallow and benefit from the high level of photosynthetic activity, as well as surface aeration and complete vertical mixing during periods of windy weather. The Kawartha Lakes have been extremely productive for many years and can be considered as naturally eutrophic waters.

The overriding factor of artificial fertilization has created different types of problems in these two major types of lakes. Enrichment studies have been carried out by the OWRC at the request of concerned cottagers on lakes in northern and central Ontario such as Little Panache (near Sudbury), Riley Lake (near Orillia), and Silver Lake (near Port Carling), and several others which can be considered representative of most lakes on the Shield. Cottage wastes appear to be the only source of artificial nutrients in these situations.

To varying degrees, these investigations revealed the classical evidence and undesirable features of induced fertilization in these thermally stratified lakes. Clues to acceleration of the natural rate of eutrophication were increased levels of phytoplankton, the onset of high levels of blue-green algae in late summer, reduced pH and dissolved oxygen in the deeper waters associated with the decomposition of settled algae and higher carbon dioxide, nutrient and iron levels, again particularly evident in the deeper water where reduction conditions were present.

Associated undesirable effects of accelerated eutrophication in one or more of these situations were a reduction in water clarity and related impairment of the recreational and aesthetic qualities of the water, objectionable accumulations of blue-green algae along shorelines and associated malodorous conditions on decomposition, a decrease in the quality of the water for drinking and domestic purposes, reduction of the area suitable for game fish owing to oxygen reduction in the deeper waters and a further reduction in fish production through elimination of desirable fish-food organisms.

In lakes like the Kawarthas, on the other hand, increased enrichment resulting from agricultural runoff, urbanization along the system and inadequate containment of cottage wastes has placed increasing stress on an already productive aquatic environment.

Here, artificial nutrient inputs have intensified the production and frequency of blooms of blue-green algae and have enhanced the production of aquatic plants to the point where many activities such as swimming, water-skiing and unimpeded boating are practically impossible.

Prolonged periods of hot, calm weather have periodically caused decomposition of algae and aquatic plants in isolated bays where limited water exchange has resulted in dissolved oxygen depletion and accompanying fish mortalities. Also, periodic winter kills of fish resulting from organic decomposition have been a recurring problem. It is certain that heavy densities of weeds in many areas interfere with the harvest of game fish and it is a moot point whether or not existing conditions actually favour or interfere with optimum game fish production.

EFFORTS IN ONTARIO RELATED TO EUTROPHICATION ASSESSMENT

One of the most sweeping and influential studies ever undertaken with respect to the more basic aspects of eutrophication is currently underway in an Experimental Lakes Area established south-east of Kenora, Ontario, by the Freshwater Institute (Winnipeg) of the federal Fisheries Research Board.

Agreements were reached between the Institute, the Department of Lands and Forests and pulp and paper companies holding timber harvesting rights to forestall any activity over a 20-year period that would affect the natural conditions of lakes within the study area.

Considerable information has already been collected by staff of the Institute on meteorological conditions, groundwater discharge and quality, lake and stream hydrology, and physical, chemical and biological attributes of the waters in question.

A minimum number of smaller lakes in the study area are to be selected for controlled additions of nutrients and other substances to determine causative relationships in lake enrichment phenomena and to demonstrate how accelerated eutrophication of surface waters can be kept under control.

This entire program is of fundamental importance to a large proportion of our recreational lakes. Since the waters under study are typical of the relatively unproductive waters throughout the Precambrian Shield, the findings will be generally applicable throughout central and most of northern Ontario.

In a more practical vein, but equally as important, is a two-year investigation carried out by the OWRC on the Muskoka Lakes, which terminated this past fall. The overall objective of this program was to determine the current trophic status of various portions of the Muskoka Lakes system, to assess the rapidity with which changes are occurring and to promote remedial measures before the existing good water quality is jeopardized.

The Muskoka Lakes provided a perfect area of investigation; that is, within the one system it was possible to find

examples of nutrient-poor, nutrient-rich and various intergrading types of lakes and bays - some affected by cottage wastes only and others by both cottage and municipal development.

During 1969 phytoplankton, zooplankton and bottom fauna populations were evaluated in the light of physical measurements, nutrient determinations and other water chemistry analyses, dissolved oxygen profiles and bottom sediment types.

Primary productivity assessments were made by means of radioactive-labelled carbon uptake studies. Algae growth potential measurements were conducted under controlled conditions in the laboratory and in plastic bags submersed in the lakes in order to determine what nutrients were limiting algal growth.

The 1970 phase of the study provided a shift in emphasis to defining the relative importance of various sources of nutrients such as nitrogen, phosphorus and carbon. This information will be combined with results of nutrient analyses completed for stations throughout the entire lake to develop a total nutrient budget for the Muskoka system.

This latter requirement necessitated an extremely detailed approach which involved a questionnaire survey of cottages, collection of soil water for nutrient analyses, evaluations of nutrient translocation to the water, assessments of septic tank performance, calculations of loadings from sewage treatment plants and measurement of import and export of nutrients between bottom sediments and overlying water.

Summarization of the data generated by this study should afford a much better understanding of the recreational lakes problem since the Muskoka Lakes area, as that involved in the Kenora District Studies, is generally representative of geological and topographical conditions throughout a large portion of our vacation and wilderness areas. A number of sectional reports are to be issued over the next several months, dealing with various phases of the Muskoka program.

Another most significant development in 1970 was the start of a 'task force' approach involving combined cottage inspectional and water quality evaluation efforts on the part of staff of the Ontario Department of Health and the OWRC.

The purpose of this ongoing program is to single out malfunctioning or inadequate waste treatment systems so that troublesome situations can be corrected and to provide an assessment of existing water quality for each lake under review. Another aspect of the program relates to an intensification of efforts to evaluate the suitability of all new cottage lots on unserviced land proposed for development.

Major emphasis in 1970 was directed to the inspection of cottages and lakes in the Kawartha Lakes region, in Algonquin Park, in the Muskoka District and in the Thousand Islands area of the St. Lawrence River, although a number of other lakes were included.

Of more than 4500 cottage premises investigated by the Department of Health during the past summer, 66 per cent had waste treatment systems rated as satisfactory, 15 per cent were reported to be unsatisfactory and 19 per cent were categorized as potentially polluting.

Correction activities commenced on September 1 and agreement was reached with 75 cottagers concerning the implementation of remedial action for unsatisfactory systems. Although excellent co-operation has been volunteered by cottagers so far, health personnel now have the authority to enforce changes when necessary.

For cottage subdivision developments, applications are presently reviewed by the Department of Health and the OWRC for comment prior to final review procedures carried out by the Department of Municipal Affairs. Lots created annually by registered plans of subdivision in unserviced areas number approximately 11,000, while an additional 4,000 lots are created by severance with the consent of the Minister of Municipal Affairs. For the latter type, reinforcement of inspection and review procedures carried out by local public health authorities is now being provided under the new program.

THE KAWARTHAS SYSTEM - ANOTHER CHALLENGE

While the findings of the recent OWRC program on the Muskoka Lakes will be generally applicable to other Precambrian waters, this study will not provide a definition of water quality management relationships for already eutrophic waters such as exist along the Trent and Rideau systems and elsewhere in the more fertile southern part of the Province.

In order to better understand factors influencing water quality in such areas, plans are now being formulated by the OWRC for a water management evaluation of the entire Trent River-Kawartha Lakes system between Lake Simcoe and the Bay of Quinte which will set a trend for future water management studies.

This program will result in the definition of a total water resource management plan that would take cognizance of all human, social and economic factors which do or should influence the pattern of water resource utilization throughout the waterway.

Fulfillment of this complex study will require considerable co-ordinated planning between a number of government departments. A start will be made in 1971 and it is anticipated that the study will extend over a three-year period.

WHAT MORE IS NEEDED?

Increased emphasis must be devoted to certain aspects of the recreational lakes problem in order to maximize progress in maintaining good water quality. The important needs are as follows:

(1) While provision has now been made by regulatory agencies for cottage-by-cottage inspections on a long-term basis, a much better definition of what constitutes a satisfactory septic tank installation under variable circumstances is a pressing requirement. Satisfactory guidelines have not yet been clarified to adequately demonstrate the interrelationships of such factors as soil depth, soil type and permeability, slope, vegetative cover and distance to water, as they affect septic tank performance.

While the Muskoka Lakes study will assist in this regard, more work is likely to be required for Precambrian areas and certainly for the deeper, more alkaline soils that characterize the Kawartha Lakes and other southern waters.

(2) Increased attention must be devoted to determining satisfactory alternatives to septic tanks for areas where such systems are inadequate. In rocky areas where extremely shallow soil conditions are present provision of collection and disposal facilities for total containment-pumpout systems may be the only workable solution.

However, research into improved waste incineration units, chemical precipitation of nutrients within small utilized systems and the possible complexing of phosphate by introducing iron compounds to the system or to tile bed runs, is urgently required.

Water quality considerations must be eliminated as a constraint on cottage development as all translocation of cottage-source nutrients must be eliminated if we are to do other than merely delay the inevitable consequences of artificial enrichment.

(3) More restrictive appraisals of cottage subdivision and lot severance applications must be implemented immediately. Past abuses, such as the installation of septic tanks in bald-rock areas or in low-lying areas characterized by elevated water tables, should not be condoned.

(4) A satisfactory means must be found to dramatically accelerate progress in the inspection of existing cottage waste treatment systems.

Provided with workable and interpretable guidelines, and supported firmly by regulatory agencies to whom they would report. Cottagers' Associations might provide an effective inspection and self-policing service.

(5) The detergent industry should be required to market only phosphate-free washing compounds in Ontario's vacation areas where the lakes are characterized by soft water and where soap products or phosphate alternatives perform adequately. It is time for the industry to support bold initiatives to reduce the potential of phosphorus pollution where effective measures are possible. In addition to the aforementioned step, public education campaigns are required to steer the cottager away from taking "hard" detergents to the lake.

(6) Each proposed cottage subdivision should not be approved until a survey has been carried out to determine the impact of the proposed development on the total environment and to formulate controls adequate to protect water quality. This would ensure that aesthetic and scenic values will be preserved, maintain safe and enjoyable boating and swimming, and reduce noise and activity levels consistent with a satisfactory cottaging experience.

HOW CAN THE COTTAGER HELP?

Cottagers, either individually or as associations, should exert influence to ensure that the aforementioned measures are implemented to enhance future prospects for our recreational waters.

In a more direct way, each cottager can do his part by using phosphate-free washing compounds and by ensuring that his waste treatment system conforms to present standards and is operating efficiently.

Neighbouring cottagers should be encouraged to do likewise and situations such as effluent ponding or surfacing, which are obviously contributing to water pollution, should be brought to the immediate attention of local public health authorities.

Cottagers having any doubt about the possibility of nutrients reaching the lake from their treatment systems should refrain from installing automatic dishwashers which require high-phosphate cleansing products (a surprising number of cottagers have them).

Another disconcerting fact is that in well-established vacation areas such as the Muskokas, lawns have been developed at many cottages and fertilizers are applied each year to promote more vigorous growth.

Pesticidal spraying or fogging in the vicinity of cottages produce extremely temporary benefits and usually do not justify the hazard involved in contaminating the nearby water.

The outboard motor is extremely inefficient and the pollution of small lakes by hydrocarbon and phenolic constituents resulting from excessive operation of high-powered boats is a very significant threat.

Altogether, modern technology has allowed the cottager to indulge himself in numerous ways which, while personally satisfying, are creating cumulative stresses on the aquatic environment. Cottagers must begin to accept their individual responsibilities in refraining from practices which will undermine water quality for future generations.

Pollution might be considered as a product of excesses - too many people, too much waste, too many conveniences, too much side-stepping of essential controls and excessive self-seeking at the expense of the general public interest. We must become much more critical of vacationland development - at least until our understanding and translation of ecological relationships allows us to live with nature without upsetting her delicate balances.

BIOLOGICAL EVALUATION OF WATER QUALITY

by

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BIOLOGICAL EVALUATION OF WATER QUALITY

INTRODUCTION:

From the inception of the Ontario Water Resources Commission in 1956 until 1964, the detection of water pollution was almost exclusively dependant upon routine chemical and bacteriological analyses with limited attention to biological parameters. Concentrations of BOD, dissolved and suspended solids and excessive total coliform levels were the major criteria of impaired water quality. Effort on biological aspects was devoted mostly to the identification and enumeration of phytoplankton populations which received attention by causing operational and taste and odour problems in domestic water supply systems utilizing surface water sources. Other phases of biological studies such as the control of aquatic vegetation and laboratory fish bioassays were in the embryonic stages of development. In 1964, the introduction of the concept of using biological parameters to assess water quality led to a broader ecological approach to water pollution problems. This presentation will describe the role of biological assessments in the water quality evaluation programme of the OWRC.

FRESHWATER ECOLOGY

Prior to an elaboration on specific investigative approaches, a brief introduction to freshwater ecology is essential.

Life in surface waters may be organized into three categories - the producers, consumers and decomposers. These three forms of life are interdependant and are constantly exchanging living and non-living materials with their physical environment.

Producers, represented by algae and aquatic plants are self-subsistent, manufacturing their own food according to the principles of photosynthesis. The physical environment provides the carbon dioxide, water, mineral salts and trace elements required for the production of organic matter. The consumers on the other hand, cannot produce their own food and are directly or indirectly dependant upon plant life for subsistence. Zooplankters feed on algae, aquatic invertebrates feed on algae and zooplankters and small fish may be dependant upon any single group or combination of these. Decomposers feed on waste products and dead producers and consumers. Bacteria and fungi are the decomposers which convert organic matter to a form which once again may be utilized by the autotrophic producers.

The balance in which the various components of aquatic life exist is governed almost entirely by the physical and chemical characteristics of the surrounding water. The survival of each species is dependant upon specific physical and chemical factors and if tolerance ranges relative to these factors are exceeded, the biological association will be noticeably altered. From a study of characteristics of the plant or animal population, an experienced observer is able to categorize the status of water quality in the lake or river under consideration.

USE OF BIOLOGICAL PARAMETERS

Aside from answering the fundamental question of the effect of discharges of combinations of discharges on life in the receiving water, biological studies have several other advantages.

Of greatest significance is the potential of biological surveys to reflect adverse conditions of water quality over extended periods. This asset applies mainly to studies of the bottom macroinvertebrate association which is virtually sedentary, unlike fish and phytoplankton. Often, pollutants are released intermittently and without automatic monitoring devices these discharges may go unnoticed. However, damage to the bottom fauna population is easily detected weeks after the discharge occurred.

Other advantages of the biological approach include the ability to monitor gradual changes in the environment and to establish trends in water quality. Changes in chemical parameters may be so small that their accurate detection may be impossible or their significance unappreciated. For example, the effects of subtle changes in concentrations of nutrients may be readily detected by regularly monitoring phytoplankton populations. Alterations in the characteristics of algal associations reflect these minute changes and allow the prediction of troublesome algae accumulations.

Although a pollutant may be identified in a water sample collected well downstream from the source of contamination, the origin of the contaminant may remain a mystery. The slug of pollution may have been translocated and diluted by currents so that samples taken upstream but below the source may not contain detectable concentrations. A survey of the biota will yield the necessary information to pinpoint the source.

Finally, the biological method is useful in monitoring wastes discharged at very low concentrations but which have the propensity to accumulate in the aquatic food web. Some heavy metals and readionuclides may be discharged to the aquatic environment at levels conforming to drinking water standards and thus pose no immediate threat to human health. However, their accumulation in freshwater organisms is of considerable significance for the survival and well-being of aquatic species.

INVESTIGATIVE APPROACHES AND SURVEY TYPES

Investigative approaches by biologists may include one or more of the following: biological surveys to study the effects of pollution including aquatic enrichment on the quantitative and qualitative aspects of aquatic communities;

field and laboratory fish toxicity and bioassay studies to determine the toxic properties of waste discharges and flavour evaluations where tainting of fish flesh is a potential hazard.

Field Surveys:

Biological surveys may take one of four forms. The spot survey is designed to provide an immediate answer to the effect of pollution in a specific local situation. In most cases, some urgency is involved so that steps may be taken to hasten effective remedial action. Watershed surveys are conducted to evaluate the overall condition of entire watersheds and to assess the impact of each specific source of pollution on the watershed as a whole. These surveys are usually a co-operative effort between biologists and engineering staff performing water quality monitoring and waste assimilation studies. Evaluations of existing water uses and water use potential usually form an important segment of the watershed survey programme. Results of watershed surveys serve as baseline data for subsequent surveillance surveys used to monitor water quality at certain key stations. Alterations in the water pollution status as a result of wastes from new sources or the implementation of improved waste treatment facilities are indicated by surveillance surveys. Special surveys, the final type of biological survey, are undertaken to increase the value of the former three. Studies of unusual types or combinations of pollution, of new sampling techniques or of assessments of unpolluted water for comparative purposes are among those conducted in special surveys. Often these studies are undertaken within the framework of the aforementioned three types.

Biological surveys in the narrowest interpretation involve a study of the distribution and abundance of aquatic plant and animal communities as described earlier. Sampling locations are situated above and below pollution sources at sites which are ecologically similar, i.e. similar bottom types and flow characteristics. Each major niche such as riffles and pools receives attention. An attempt to qualitatively and quantitatively sample the bottom fauna, phytoplankton and fish is made at each station although major sampling effort is devoted to the segment of the association which yields the most meaningful results for the particular situation.

Following collection, the organisms are preserved, enumerated and identified and results are tabulated. Interpretations are based on the total numbers and different types of life found, along with the relative abundance of forms regarded as intolerant or tolerant to pollution. For example, a cleanwater association is usually characterized by a wide variety of species with no outstanding numerical abundance of one group. In contrast, an organically-enriched community is typified by limited variety and numerical predominance of a few different forms capable of tolerating reduced oxygen tensions.

Studies of aquatic associations are always accompanied by physical and chemical data obtained during routine water quality surveys or during the biological survey. Information yielded from chemical analyses usually aid in the interpretation of biological data . Of major significance in organic pollution are dissolved oxygen determinations (often conducted on a 24-hour round-the-clock basis) along with concentrations of biochemical oxygen demand, dissolved and suspended solids and total and soluble nutrients such as nitrates and phosphates. Determinations for toxic pollution require an understanding of the industrial process involved.

Toxicity and bioassay studies:

It is often necessary to include toxicity and bioassay studies as an integral part of a watershed survey to clarify the significance of individual industrial and municipal discharges. To establish median tolerance limits for aquatic organisms, standardized bioassay tests are conducted on industrial waste components and receiving waters. Fish are usually the test subjects although on-the-spot toxicity tests on bottom-dwelling fish-food organisms have also been conducted. In biological surveys where the production and harvest of fish are beneficial uses, toxicity and bioassay tests are usually conducted to establish the degree of treatment or dilution required to safeguard fish life. Wastes containing heavy metals, cyanides, pesticides and toxic gases such as ammonia or hydrogen sulfide require stringent controls and frequent surveillance. A mobile laboratory is now under construction which will be used to carry out toxicity and bioassay studies on location, in order to assist particular industries with their industrial waste problems and to demonstrate the value of bioassays as an effluent monitoring tool.

Fish flavour evaluations:

Some processing wastes impart unpleasant tastes to the flesh of fish swimming in the vicinity of the plant. Where sport or commercial fishing are important uses of the receiving water, fish flavour evaluations are conducted. A panel of at least six people taste samples of suspect and untainted fish of the same species and cooked identically. The samples are presented in random order to the panelists who then record the presence or absence and intensity of foreign flavour. Wastes from pulp and paper mills and refineries are often associated with fish flavour impairment.

Eutrophication studies:

Early in 1969 OWRC biologists initiated a two-year investigation on the Muskoka Lakes. The objective of this programme is to determine the current trophic status of various portions of the Muskoka Lake system, to assess the rapidity with which changes are occurring and to promote remedial measures before the existing good water quality is jeopardized.

During 1969 phytoplankton, zooplankton and bottom fauna populations were evaluated in the light of physical measurements, nutrient determinations and other water chemistry analyses, dissolved oxygen profiles and bottom sediment types. Primary productivity assessments were made by means of radioactive-labelled carbon uptake studies. Algae growth potential measurements were conducted under controlled conditions in the laboratory and in plastic bags submersed in the lakes in order to determine what nutrients are limiting algal growth. Plans for the 1970 phase of the study provide a shift in emphasis to defining the relative importance of various sources of nutrients such as nitrogen, phosphorus and carbon. This information will be related to nutrient analyses completed last year throughout the entire lake system and thus make possible the development of a total nutrient budget for the Muskoka Lakes. Evaluations of the contributions of nutrients from municipal, resort and cottage waste treatment systems will provide guidelines for implementing necessary controls.

PRESENT AND FUTURE GUIDELINES

Priorities for water quality studies are established

through mutual consultations between biologists and engineers responsible for control of industrial waste discharges and the monitoring and forecasting of water quality. The nature of a survey is dictated by the physical characteristics of the water body in question, along with the magnitude and complexity of the waste inputs. Some investigations may be conducted solely by engineering staff or by biologists, depending upon the purpose of the study. In large-scale surveys, however, a multidisciplined approach has been adopted to avoid duplication of effort and to provide a more complete and in-depth evaluation. In a recent survey of the Ottawa River, a team of chemists, engineers, bacteriologists and biologists worked together to define and quantify waste inputs, to determine pollution levels in the river, to assess the self-purification capacity of the river and to document the effects of pollution on beneficial uses. This approach is now setting the pattern for future watershed surveys.

To document how pollution interferes with beneficial uses is now foremost in the minds of survey planners. In the framework of our present-day society, a healthy industrial community is fundamental to a sound economy and the translocation of adequately-treated wastes must be recognized as an important use of many watercourses. The challenge which we face today is to provide a framework which will allow for the definition of valid water uses in our lakes and watercourses and the formulation of adequate water quality controls to ensure the future success of multiple-use management. Towards this end, OWRC personnel are presently in contact with and receive co-operative effort from related governmental agencies such as the Department of Health, the Department of Lands and Forests, the Conservation Authorities and the Department of Tourism and Information; however, the developing philosophy of water resource management as it relates to the responsibilities of various levels of government must be translated into a manageable process and explained in practical terms to ensure subsequent public understanding and involvement.

CONCLUSION

The responsibility of the biologist in formulating water management policies is becoming increasingly important as greater and more complex demands are being placed on the freshwater environment. Development of improved water

quality criteria and standards will often be based on the biological ramifications of the specific pollutant or combinations of pollutants. More factual information will have to be formulated for both the obvious and subtle effects of contaminants on aquatic life (e.g. toxic and sublethal action). Complicating matters is the definite time-lag which exists between the manufacture of an endless list of new products and our ability to define and mitigate the consequences of attendant waste materials. Recent pollution problems, particularly those associated with mercury contamination, have demonstrated the need for more stringent requirements to induce industry to adopt a 'materials-balance' approach to their processing. Adoption of such an approach will ensure a complete understanding of the fate of all materials involved in industrial processing, including those discharged to receiving waters.

One of the most pressing needs relative to our current environmental crisis is the development of an ecological awareness and an understanding of environmental relationships by the general public. Resource managers should co-operate with educators to promote a proper infusion of ecology into school curricula at every academic level. To underline that ecologists still have an important job of salesmanship, in spite of the current publicity and attention accorded the many-sided problem of pollution, I quote a statement from Business Week referred to in the 1970 April issue of Consumer Reports ...

> "Taking care of water pollution is money down the drain says William Geissman, manager of technical services at National Lock Co., in Rockford, Ill. 'It adds nothing to the product, and about all you can get out of it is a little goodwill in the town...' He says his company has engaged a consultant and knows exactly what to put in to clean up its pollution. 'But we're trying to hold back as long as we can, hoping to find a more economical way'."

It would be a grim paradox if, in 'hoping to find a more economical way' man puts himself out of business entirely.

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ABOUT MERCURY IN FISH

ONTARIO DEPARTMENT OF LANDS AND FORESTS

WHAT IS MERCURY?

Mercury (Hg) is one of the heavy metals. It can occur in many chemical compounds, but cannot be decomposed. Mercury is a liquid at room temperature, but when combined with other elements, the resulting compound is usually a solid. Mercury and many of its solid compounds are nearly insoluble in water. If introduced into lakes or streams, they tend to sink to the bottom.

IS MERCURY FOUND IN NATURE?

Mercury is not generally found naturally in the elemental (liquid) form. It is found in small but varying amounts in rock and soil, usually combined with sulphur. Trace amounts occur naturally in plants and animals, and therefore, in food.

IF TRACE AMOUNTS OF MERCURY ARE FOUND NATURALLY IN PLANTS AND ANIMALS, WHY IS THERE SO MUCH CONCERN ABOUT MERCURY IN FISH?

During the past year fish in some Ontario waters have been found to contain mercury in concentrations exceeding that which is acceptable for fish. Almost all of the mercury in fish and other animals exists in a highly toxic form known as methyl mercury. It is readily absorbed into the body when contaminated fish are eaten. Because methyl mercury is excreted very slowly, repeated eating of fish (or other food) containing more than the acceptable concentration of mercury can result in harmful mercury accumulation in the body. If sufficient quantities are eaten, nervous disorders and even death can result.

HOW ARE MERCURY CONCENTRATIONS IN FISH MEASURED, AND HOW ARE THE RESULTS REPORTED?

Measuring mercury is a complicated laboratory procedure that can be done only with specialized equipment and trained analysts. The results of a mercury analysis are reported in parts per million (ppm). One ppm indicates one part of mercury in one million parts of fresh (water not removed) fish flesh, and is equivalent to one ounce of mercury in approximately 60,000 pounds of fish.

WHAT IS THE MAXIMUM ACCEPTABLE CONCENTRATION OF MERCURY IN FISH FOR HUMAN CONSUMPTION, AND HOW WAS THIS STANDARD CHOSEN?

The legally accepted level in Canada for mercury in edible parts of fish is set at ½ ppm by the Federal Food and Drug Directorate. This standard was chosen on the basis of animal toxicity experiments and studies of humans poisoned by mercury from contaminated fish and shellfish in Japan. It contains a safety factor to protect individuals who are heavy fish eaters or who may be unduly susceptible to mercury poisoning.

IS THE ½ PPM MERCURY LEVEL USED WORLDWIDE?

No, several countries including the U.S.A have accepted this standard, but it is not universal. In Sweden, only fish containing less than 1/5 ppm are considered suitable for unlimited human consumption, with the recommendation that fish in the range 1/5-1 ppm not be eaten more frequently than once per week. Average fish consumption in Sweden, however, is roughly 2 to 3 times greater than in Canada.

HOW DANGEROUS IS THE CONSUMPTION OF FISH WITH MORE THAN ½ PPM OF MERCURY?

This would depend on the frequency of fish consumption, the amount of fish eaten, and the mercury concentration in the fish consumed. In addition, there is considerable variability among individuals in susceptibility to mercury poisoning. No danger is likely with occasional (once per week) consumption of fish containing ½-1 ppm, with the exception of pregnant women. The human fetus appears to be more susceptible to methyl mercury than the mother. Women of child-bearing age should probably not consume any fish containing more than ½ ppm mercury.

WHAT ARE THE SYMPTOMS OF CHRONIC MERCURY POISONING?

Most of the symptoms are related to changes in the nervous system. Symptoms include loss of peripheral (tunnel) vision, loss of motor coordination and resultant inability to walk, grasp objects, coordinate body movements, etc. Ultimately coma and death can result.

IS MERCURY TOXIC TO FISH AND OTHER AQUATIC LIFE?

Certain mercury compounds are highly toxic to fish and lower aquatic animals when dissolved in water. However, fish kills due to mercury are not known to have occurred in Ontario. Mercury deposits in lake and river sediments from industries yield concentrations in water that are extremely low (near or below the minimum limit of detection). These minute concentrations are sufficient to cause accumulation of mercury in fish flesh, but are probably too low to be toxic to fish. Adverse effects on fish of mercury stored in the flesh are possible, but these effects, if they exist, have not been detected.

HOW MUCH MERCURY IS FOUND IN FISH FROM ONTARIO WATERS?

In Ontario waters where there are no known local sources of mercury from human activities in the drainage system, most fish contain less than ½ ppm of mercury. In waters where there is such a known local mercury source, pike, pickerel and bass often contain 2 or 3 and up to 15 ppm. About 40 waters lacking known local sources of mercury from human activities have been found to contain some species of fish averaging approximately ½-1 ppm mercury. The reason for these apparently elevated mercury concentrations is unknown at this time. In all waters there is considerable variation in mercury concentration among and within various fish species. Some species such as whitefish and bullheads, are often low in mercury even in waters where mercury concentrations are high in other species.

HOW DO FISH BECOME CONTAMINATED WITH MERCURY?

Fish take in mercury through the skin and gills, as well as in their food. Various types of mercury compounds, both industrial and natural geological compounds are nearly insoluble in water. These compounds settle on the river or lake bottom, and are converted by bacteria in the bottom sediments to methyl mercury (Answer No. 3). Methyl mercury is soluble in water and enters fish and other aquatic organisms which are consumed by fish.

DO ANIMALS OTHER THAN FISH ACCUMULATE EXCESS MERCURY?

Yes, birds have been found in several places in Canada with high levels of mercury thought to be caused by consumption of seed-grain treated with a mercury fungicide. Very limited testing of other aquatic life (ducks, frogs, lower animals) has given indication of some elevated mercury levels, but to date the contamination does not seem to be as widespread as in fish.

HAS MERCURY POISONING BEEN DOCUMENTED IN ONTARIO OR OTHER PARTS OF THE WORLD?

Symptoms of mercury poisoning due to eating contaminated fish have not been diagnosed in Ontario or other parts of Canada. Elevated blood and hair levels of mercury have been noted in some Ontario residents who had eaten fish with more than ½ ppm mercury content, but even in these individuals, blood and hair levels were well below those found in persons with symptoms of mercury poisoning. In two outbreaks of poisoning in Japan some years ago, about 150 persons became ill from eating mercury contaminated fish and shellfish; of these, over 40 died. A few other mercury poisoning incidents have been noted, the most recent being in New Mexico, where a family consumed pork which had been fed grain treated with mercury fungicide.

IS IT SAFE TO DRINK FROM A LAKE OR STREAM KNOWN TO CONTAIN MERCURY?

As far as mercury is concerned, the water is safe to drink. However, water from lakes or streams should not be consumed unless it has been tested and found potable, or is boiled or chlorinated.

DOES COOKING ALTER THE MERCURY CONTENT OF FISH?

No, not to any significant degree.

WHAT ONTARIO WATERS CONTAIN MERCURY CONTAMINATED FISH?

Several waters scattered over the province contain species of fish with mercury concentrations well in excess of ½ ppm. These problem areas, all associated with mercury discharges from chlorine-alkali plants or pulp and paper mills are: portions of the English-Wabigoon-Winnipeg River system, St. Clair River, Lake St. Clair, Detroit River, eastern Lake Ontario and the St. Lawrence River, and the Ottawa River downstream from Ottawa.

In addition to these waters about 40 lakes have been found containing some fish of some species which are above the ½ ppm level (mostly ½-1 ppm). In these waters, no local sources of mercury from human activities are known; mercury deposits in watersheds or atmospheric fallout are possible sources.

WHAT ARE THE MAJOR USES OF MERCURY, AND WHICH USES ARE THOUGHT TO BE IMPORTANT IN CAUSING ELEVATED MERCURY CONCENTRATIONS IN FISH?

Uses of mercury include: production of chlorine and alkali, electrical instruments production, pulp and paper processing, seed-grain treatment, pest control in fruit and vegetables, lawn treatment, paint manufacturing, and pharmaceutical and dental preparations. Other chemicals have replaced mercury compounds for some of these industries. Only some chlorine alkali plants and pulp and paper mills were important sources of mercury in fish in Ontario. Substitute chemicals have completely replaced mercury compounds in the pulp and paper industry. Mercury losses from chlorine-alkali plants have been greatly reduced since May 1970.

Considerable but unknown amounts of mercury are released to the atmosphere through burning of coal, oil and waste materials. To what extent the fallout from this burning of fuels and wastes has contributed to the mercury content of fish is completely unknown at present.

HOW WIDESPREAD IS THE MERCURY PROBLEM?

The problem is actually world wide, with Japan, the U.S., Sweden and other countries being affected. Provinces other than Ontario also have elevated mercury concentrations in fish, although Ontario and Manitoba have probably received the most publicity concerning the mercury content of fish.

WHAT IS THE ONTARIO GOVERNMENT DOING TO SOLVE THE MERCURY PROBLEM?

Lands and Forests has been collecting fish for mercury analysis from all areas of the province. Major waters with mercury contaminated fish have now been identified. Commercial fisheries on these waters have been closed and sport fishermen have been warned not to eat their catches. Investigations to gain further understanding of the mercury problem are underway.

The following are activities of the Ontario Water Resources Commission: study of patterns of mercury deposition in lake and river bottoms and methods of accumulation of mercury by aquatic life; evaluation of possible methods of deactivating or removing mercury sediment deposits and their safe disposal; enforcing limitations on the discharge of mercury compounds into waters.

The O.W.R.C. performs most of the mercury analysis on fish collected by Lands and Forests. The Canada Center for Inland Waters has undertaken basic research concerning aquatic mercury compounds. The Federal Department of Fisheries and Forestry tests commercial fish shipments. Those that exceed ½ ppm mercury level are destroyed. The Ontario Department of Health is measuring the mercury content in hair and blood samples from persons living in the vicinity of lakes with highly contaminated fish.

WHY HAS THE SPORT FISHERY NOT BEEN CLOSED ON WATERS WITH FISH HAVING A HIGH MERCURY CONTENT, AND WHY ARE COMMERCIAL FISHERIES STILL OPERATING ON WATERS WITH SLIGHTLY ELEVATED MERCURY LEVELS IN FISH?

Although sport fisheries in mercury affected waters have remained open to allow continued recreational use, fishermen have been warned not to eat their catches from these waters. On waters with slightly elevated levels in fish, those to be offered for sale are sampled and tested. Catches of fish above the ½ ppm mercury level are destroyed, but much of the commercial catch is below the ½ ppm mercury standard, and safe for human consumption.

HAS THE MERCURY PROBLEM HAD AN ADVERSE ECONOMIC IMPACT? IF SO, WHAT HAS BEEN DONE TO HELP THOSE AFFECTED?

Commercial fishermen have been required to cease operations on waters containing mercury contaminated fish. On other waters where mercury problem is not as serious, a portion of the commercial catch has had to be destroyed. Resort owners on waters having fish with mercury concentrations above the acceptable level reported loss of business. Some government assistance is being made available to resort owners. Joint Provincial-Federal loans and loans administered by the Ontario Development Corporation are available to commercial fishermen.

HOW LONG IS THE MERCURY PROBLEM EXPECTED TO LAST?

The answer to this question is not yet known, but some background information may be helpful. Trace amounts of mercury are a natural part of the environment. While mercury compounds can be transformed and transported, they cannot be destroyed. It is unlikely that anything can be done about the levels of mercury in fish from waters where there are no known local human mercury sources. In waters having received industrial discharges of

mercury, although these discharges have been greatly reduced, the mercury previously deposited is a continuing source of mercury in fish.

The Ontario Water Resources Commission is studying the feasibility of dredging mercury deposits from lake and river bottoms. Other methods such as physically covering mercury deposits or chemically deactivating them have been proposed, but it is not yet known if any of these might be successfully used. Unless some method of stopping the movement of mercury out of bottom sediments is developed, the mercury problem is likely to be with us for years to come.

CONCLUDING STATEMENT

Because the mercury problem is relatively new, a great deal of information is lacking that would be useful in answering some of the questions raised in this paper. The answers given here make use of the most recent information available, but it is probable that some answers may require modification as the results of new studies become available.

Four departments of the Ontario Government and at least three departments of the Canadian Federal Government are spending considerable time and money to ensure that fish offered for commercial sale in Canada are safe with respect to mercury content. Every effort is being made to see that sport fishermen are supplied with up to date information concerning the safety of a favourite activity - eating their angling catch.

OIL AND HAZARDOUS MATERIAL POLLUTION CONTINGENCY PLAN

INTRODUCTION

The spill of oil and other hazardous materials has always been of concern to pollution control authorities. However, it has taken actual spills to dramatize the need to develop organized plans to cope with major spills. The Ontario Water Resources Commission recognizes that pollution potential exists in relation to the oil and gas well drilling industry in Lake Erie, and while the industry is well regulated and essentially geared to prevent and control losses of materials from their operations, extreme care must be continually taken to avoid pollution. While the probability of oil production in Lake Erie may not be very great, the possibility remains; therefore, the capability for handling oil losses must be assured. Oil and other material spills from increased vessel traffic and related industrial operations as well as the potential of pollution from offshore petroleum activities in Lake Erie emphasized the need for Ontario to formulate a contingency plan for the spill of oil and other hazardous materials.

In most cases to date the spills have been either local in extent or have readily dispersed in the lake. Increasingly, however, oil deposits and accumulations have been noted along the beaches especially in areas of intensive vessel activities attesting to the growing menace of this source of pollution. In Lake Erie alone, numerous incidents were sighted in 1969 with increased public awareness probably accounting for the greater number of occurrences reported. In most of the cases investigated on Lake Erie, no definite connection between the report and the source could be established. However, the circumstances usually indicated vessel traffic as the most probable cause.

The purpose of this brief is to outline the Commission's present oil pollution control activities and plan for contingencies arising from spills in the Province of Ontario.

CURRENT PROCEDURES FOR SPILLS

Surveillance is carried out by the OWRC using regular vessel and aircraft patrols. As well, close liaison is maintained with the Federal Ministry of Transport patrols in the shipping lanes of the Great Lakes. This is supplemented by discoveries by the general public and other agencies. An

international notification system exists whereby this Commission is notified by United States officials who are part of the U. S. National Contingency Plan whenever a report of a spill is made. Similarly, the OWRC advises the appropriate U. S. federal authorities, either the U. S. Coast Guard or the Regional Environmental Protection Agency office, of reports on spills. Individuals, industries and utilities, such as marinas, waterworks, etc., which may be adversely affected by the spill are contacted and warned of the impending problem. Investigations are commenced to determine the source, type and quantity of material spilled, its probable movement and the threat posed to property and water uses.

It is recognized that the working liaison and warning system that has been established between the OWRC and the United States, Federal and State agencies for the purposes of surveillance and notification of spills on the Great Lakes and their interconnecting channels requires strengthening to improve the capability for dealing with emergency conditions. While the present system of surveillance and notification is useful in tracing and determining the extent of a spill, it does require organization for the mobilization of available resources for clean-up should a problem develop. Fortunately, to date, organized clean-up operations have not been required on a major scale.

STATUS OF CONTINGENCY PLANNING

Charged with the responsibility of pollution abatement in the Province of Ontario, the OWRC has assumed the lead role in contingency planning in Ontario on the Canadian side of the Great Lakes.

In Ontario, concerned industries, notably in the Western Lake Ontario and in the Sarnia areas have initiated the development of local contingency plans. The OWRC has solicited the co-operation of all industries in the Great Lakes Basin in Ontario in preventing accidental losses and requesting the development of industrial contingency plans to control pollution when unavoidable losses of oil or other materials do occur.

SCOPE OF ONTARIO CONTINGENCY PLAN

The objective of the Ontario plan is to establish a working system whereby all the avilable resources of manpower, materials, equipment and technology can be mobilized promptly towards the co-ordinated containment and clean-up of a spill of oil or other hazardous materials to Ontario waters so that damage to the environment can be minimized. The plan permits and encourages the development of and close co-ordination with local contingency programs within the framework of the overall plan.

It is the intention of the OWRC to establish the necessary liaison with representation from agencies with direct involvementin the control of oil and hazardous material spills for the following purposes:

- maintain contact with the liaison officers appointed by industrial concerns and governmental agencies;

- promote and provide guidance in the development of local contingency planning;

- distribute up-to-date information on available resources;

- develop guidelines on techniques for containment and removal of oil and hazardous material.

The Commission has established an Operations Centre at its Head Office in Toronto to maintain up-to-date information on communication procedures, material and manpower resources and techniques for the containment and removel of hazardous material. A system of on-scene co-ordination of emergency procedures has been developed along with provision for the organization and supervision of containment, countermeasures, clean-up and restoration. The Commission is confident that this plan will provide effective emergency measures for the protection of the Great Lakes.

THERMAL POLLUTION

Thermal pollution relates to the adverse effects on water quality and aquatic life caused by heated discharged to natural watercourses. However, it must be stated from the outset that the potential thermal effects on a body of water may be either beneficial or adverse depending on the uses being made of the water. The state of the art in assessing these thermal effects is still developing; nevertheless, it is well known that certain things happen when large quantities of heat are introduced into a river or lake.

The use of cooling water is a common practice in many industrial operations, as for example, in the production of steel. Where water is scarce or expensive, cooling ponds or towers are generally used and the water is re-used again and again. Where adequate cheap supplies are available, the heated water is normally discharged directly to a river or lake after a single pass through the industrial process. To date in Ontario, and I believe in the rest of Canada, thermal pollution from industry has not been a problem. The controversy in recent years on thermal pollution has arisen largely because of the phenomenal growth of the electrical power generation industry, particularly so in the United States. In many instances in that country, a number of large power stations have been built on relatively small lakes and rivers causing ecological disruptions in the aquatic environment much to the dismay of many sectors of society. The Ontario Water Resources Commission (OWRC) is trying to ensure that the mistakes of our neighbours are not repeated in this Province.

Because of the rapidly increasing demand for electrical power which is doubling approximately every ten years in Ontario, and since the Province's hydroelectric resource is almost totally harnessed, the Hydro-Electric Power Commission of Ontario is constructing a number of fossil fuel (coal) and nuclear generating stations. The volumes of cooling water used at each plant are enormous, in the range of hundreds of thousands of gallons per minute, and because of the low thermal conversion efficiencies of these stations, approximately sixty to seventy percent of the heat generated is dissipated to the surrounding environment, mostly to the receiving waters. Because temperature is considered to be the primary control of life on earth and is important in a body of water, and since it can determine the

species that will live and reproduce, ecologists are deeply concerned with the threat to fish and other aquatic life forms which is likely to occur in the future due to the predicted increases in power demands.

What constitutes thermal pollution?

As water temperature rises in a body of water due to heat imputs, dissolved oxygen levels decrease although at the same time under these circumstances fish actually require more oxygen in order to maintain a normal existence. Oxygen consumption, in general, doubles for every ten degrees centigrade increase in water temperature, but blood hemoglobin in fish has a reduced affinity for oxygen at increased temperatures which places the fish under undue stress. Also, sudden changes in water temperature can be lethal to fish and other aquatic organisms because of the "shock" effect. High water temperatures can also be lethal, but water temperature does not have to reach the lethal limit to exterminate a species of fish. Temperatures which favour competitors, predators, parasites and disease can destroy a species at temperatures far below those levels which are normally lethal. Changes can also occur in the biota of the aquatic environment thereby affecting the food chain which ultimately can cause changes in fish populations and movements. This is of importance where commercial or sport fishing are practised because of the attendant adverse effects which can be imposed on that industry.

Apart from the fact that elevated water temperatures can have pronounced physiological influence on all vital processes for fish including activity, feeding, growth rate and reproduction, the input of heat can effect the spawning habits of certain types of desirable species of fish which are indigenous to an area. For example, trout and other cold water game fish will not spawn in certain locations if the temperature of the waters in question becomes too high and these fish will have a tendency to migrate elsewhere. Thus, traditional spawning grounds or shoals can be eliminated.

All other things being equal, the input of heat might stimulate profuse growths of algae where such a problem did not exist before. This is important from the aspects of water supply and recreation. In water supply, massive growths of algae increase water treatment costs because of the requirements for microstraining and filtration. Also, if certain types of blue-green algae are present, taste and odour problems are

likely to be experienced with the water supply which then requires further treatment to render it acceptable for drinking purposes. The location of cooling water outfalls from thermal plants is therefore of interest to the OWRC with respect to water supply intakes for municipalities. From the recreational standpoint, increased growths of algae result in die-offs which can then be blown on to beaches and create aesthetic problems mainly associated with foul odours.

The above are some of the adverse effects of thermal pollution. However, there can be beneficial effects of heat inputs to watercourses. In winter months, heated water may prevent ice formation and promote navigation in water passages normally blocked. Fish farms could be developed under proper control, or extended periods of fish feeding could be provided during the colder months in selected locations as warm water stimulates the growth of fish food. Perhaps, swimming areas could be provided in certain cold water lakes where this type of activity is minimal, thus increasing the recreational potential of those lakes.

As stated above, thermal pollution is not a serious factor in Ontario at this time. However, it might become a problem if proper planning for the future is not carried out. The OWRC has been working closely with Ontario Hydro on this matter, especially since 1967, when the announcement was made by Ontario Hydro that a coal-fired thermal plant was to be built at Nanticoke on Lake Erie.

Apparently, the implications of a heated discharge on the small-mouth bass fishery in the Nanticoke-Long Point Bay area one of the finest fisheries of this type in North America, had not been given enough consideration by Ontario Hydro in assessing the suitability of this location. The Ontario Department of Lands and Forests claims that the temperature of Lake Erie water in the summer is already approaching the maximum tolerable limit required for spawning of small-mouth bass, and that the additional heat input in the vicinity of the shoals may be the final factor which eliminates this valuable fishing resource. To complicate matters, the announcement by The Steel Company of Canada, Limited to build an integrated steel mill adjacent to the generating station, and the expected associated industrial development, will undoubtedly affect the traditional use of the area for hunting and fishing.

The position taken within the OWRC is, not that industrial development and power generation is preferable to recreational usage, but rather, in order to avoid conflict of uses, that the potential thermal effects on the environment and existing values be taken into consideration by Ontario Hydro and other industry, along with all other relevant factors, when plans are being formulated for the construction of future thermal generating stations and industrial plants. The OWRC's objective on the subject of temperature is that there should be no change in the receiving waters which would adversely effect beneficial uses.

As a result of Nanticoke, OWRC concern was voiced to Ontario Hydro regarding future site selection for power plants. OWRC stated that the potential thermal effects on the aquatic environment must be a factor in Ontario Hydro's overall analysis of site selection. Ontario Hydro has agreed totally with this concept and several meetings have since been held. These meetings give the OWRC a chance to acquaint Ontario Hydro of existing, and future, uses of water in the designated sites of interest to Ontario Hydro and to point out potential problems that could arise as a result of heat input to the receiving waters.

Extensive joint studies are being carried out in several areas on water quality and biological parameters by Ontario Hydro and the OWRC. At Nanticoke, the Department of Lands and Forests are also assessing factors which relate to the existing fishery. Work is being done to develop a mathematical model which may be used to predict the physical influence of cooling water plumes in receiving waters. Hopefully in the years ahead, the results of these studies will aid in forecasting more precisely the potential ecological effects of heated discharges on rivers and lakes.

Because the majority of existing thermal stations and those earmarked for the future in Ontario are located on the Great Lakes system, the effects of thermal pollution on these lakes are expected to be minimal. However, localized pollution effects are being considered carefully and every effort is being made to safeguard against any problems which might arise in the future.

STUDENT STREAM OR LAKE SURVEYS

Concern for the quality of our environment has increased substantially because of visible damage to natural resources and wildlife caused by man's disruption of the natural ecosystem. The plant and animal life which is destroyed by man's activities is responsible for much of the aesthetic and economic value of water resources.

When studying natural systems, the environment, natural resources it is necessary to note all aspects of the area under study, and to observe changes brought about by all of man's activities.

STUDENT STREAM OR LAKE SURVEYS

When selecting a stream or lake for study with a student or student group it is important to have them approach the study from every aspect. The geology of the area, land use practices (agriculture, industry, municipal), run-off characteristics, erosion, construction in progress, amount of forest cover, etc., are all important considerations in the overall assessment. For example, what may not appear to affect the dry-weather flow of the watershed may have an effect during periods of heavy rain. Pollution or waste discharges should not be the primary purpose of the exercise.

It is suggested that several sites be selected which represent a broad picture of man's effect upon the waterway. For example: when surveying near a town then establish sites well above, just above, just below and well below to give a representative picture of the municipal, industrial and agricultural communities around the waterway.

The study should also encompass biological and chemical considerations in order to reflect the ecological aspects relating to the biota of the waterway.

CHEMISTRY

Many changes brought about by shoreline development projects could have an adverse biological effect upon the biota but cause little or no change in the chemical composition of the water. Changes in the chemical characteristics of water brought about by waste inputs can cause serious damage to life in the water but in almost all cases, alterations in aquatic life will be readily apparent before there has been enough change in the chemical composition to be easily measured.

Most chemical contaminants can cause visible biological damage at concentrations of only a few parts per million or even parts per billion and for this reason meaningful chemical analysis are difficult to carry out with equipment usually found in a high school laboratory. Therefore, it is strongly recommended that emphasis be placed on biological observations with use of chemical analysis only to substantiate these observations.

Temperature

Temperatures in surface waters will normally fluctuate between 0° and 25° centigrade. Most aquatic animals exhibit some sensitivity to temperature so it is important to record water temperatures during field work. Temperatures must be recorded in the field at the time of collection of any samples. A laboratory thermometer which can read to the nearest $0.1^{\circ}C$ is satisfactory.

Water has its maximum density at $4^{\circ}C$, and in the case of lakes the surface water warms up in the summer and since there is usually not enough wind to cause wave action and mixing to the bottom, the bottom water remains at approximately $4^{\circ}C$.

Solids

The solids content, both dissolved and suspended, are very important chemical measurements.

The total solids content is measured by placing a known volume of sample in a tared dish and evaporating the water to dryness at $105^{\circ}C$. The weight of the residue is then expressed in units of weight per unit volume -- usually milligrams per litre or parts per million.

The total solids is best broken into two fractions -- dissolved and suspended. If the suspended solids are less than 50% of the total, then a sample can be filtered to remove the suspended matter and then the 'total' measurement repeated on the filtrate. The suspended solids are then determined by the difference.

If the sample is high in suspended material, it can be weighed directly by filtering a known volume through a tared piece of glass fibre filter paper. If the suspended solids are more than 75% of the total, then this method would be preferred but still not manditory.

Any fraction of the solids can be ignited at $600^{\circ}C$. in a furnace in a tared crucible. The organic material and some water of hydration will be driven off and thus a conclusion as to whether the sample contained organic or inorganic matter can be drawn.

Heavy concentrations of suspended solids can be very damaging to the aquatic environment. The particles settle out and bury the bottom organisms; they block light so that normal plant growth is impeded and if the material is organic it can use up all the oxygen as it is being decomposed by bacteria.

Short-term effects of heavy concentrations of suspended solids can be caused by run-off from construction sites, etc., while prolonged effects may be due to waste disposal plant discharges, sanitary or storm-sewer discharges, livestock manure pilings, etc.

Conductivity

The electrical conductivity of water is due to the total dissolved inorganic solids concentration. It is not possible to measure solids exactly from conductivity measurements because the relationship is different for each ion, as the composition changes, so does the relationship.

However, for a given waterway under study it is useful to prepare a graph of the dissolved solids and conductivity results to determine if a relationship exists. This can be used in subsequent work as a quick measure of dissolved solids. In most conductivity in micromhos at 25°C. X 0.7 $\pm$ 0.05 = dissolved solids in ppm. Conductivity varies with temperature but some meters have a temperature correction. A good commercial meter gives the best results.

All reported results are given for a standard temperature of 25°C. and if the meter being used has no temperature correction then the water should be adjusted to 25°C. when taking a measurement. Waters up to 300 micromhos are usually regarded as "soft" and "hard" are above this.

Many ions such as Ca, Mg, Na, K, Fe, Cl, SO_4, CO_3, and HCO_3 are regularly present; their sum total is estimated by the conductivity and individual measurements are not required. If large conductivity changes are observed then a test could be set up for one or two which may be suspected, such as high Na and Cl in an area of runoff from a road using salt.

COLOUR

The colour of water is important as an indicator of undesirable effects. Natural waters are normally clean or slightly yellow, with darker yellow colours in some marshes and bogs. Any other colour is likely to be due to some waste imput.

Colour can be measured in standard units by comparison with a series of coloured dishes but a visual examination will be completely satisfactory for high school work.

pH

pH can be measured if equipment is available and it should be done in the field or within a few hours after collection as it will change with time. If measurements are made in the laboratory then the result must be reported as 'pH at the laboratory'. pH paper, which gives different colours over short pH ranges, can be used for measurements. Unless some extreme value is found, less than 5 or more than 10, then it is not necessary to place emphasis on this test.

Nitrogen and Phosphorus

These two elements are of great importance in plant growth and the natural ageing process of all waterways. However, they are usually present at levels of parts per billion and a change of a few ppb can be very significant. For this reason expensive and very reliable methods must be used. It is not recommended that these elements be included as part of a high school survey.

The effects of these nutrients are best demonstrated in the laboratory by commercial fertilizers to samples of river or lake water and observing the number of algae cells with time after addition.